TIME AND ITS MEASUREMENT

BY

JAMES ARTHUR

REPRINTED FROM
POPULAR MECHANICS MAGAZINE

CHICAGO, 1909

CONTENTS

CHAPTER I

HISTORIC OUTLINE

CHAPTER II

JAPANESE CLOCKS

CHAPTER III

MODERN CLOCKS

CHAPTER IV

ASTRONOMICAL FOUNDATION OF TIME

ILLUSTRATIONS

James Arthur

Mr. Arthur is an enthusiastic scientist, a successful inventor and extensive traveler, who has for years been making a study of clocks, watches, and time-measuring devices. He is not only a great authority on this subject, but his collection of over 1500 timepieces gathered from all parts of the globe has been pronounced the finest collection in the world. Mr. Arthur is a pleasing exception to the average business man, for he has found time to do a large amount of study and research along various scientific lines in addition to conducting an important manufacturing business in New York City, of which he is president. Mr. Arthur is 67 years of age.—H. H. Windsor.

CHAPTER I

HISTORIC OUTLINE

Time as an abstraction.—Ancient divisions of day and night.—Night watches of the Old Testament.—Quarter days and hours of the New Testament.—Shadow or sun time.—Noon mark dials.—Ancient dials of Herculaneum and Pompeii.—Modern Dials.—Equation of time.—Three historic methods of measuring time.—"Time-boy" of India.—Chinese clepsydra.—Ancient weather and time stations.—Tower of the winds, Athens, Greece.

TIME AND ITS MEASUREMENT

CHAPTER I

Time, as a separate entity, has not yet been defined in language. Definitions will be found to be merely explanations of the sense in which we use the word in matters of practical life. No human being can tell how long a minute is; only that it is longer than a second and shorter than an hour. In some sense we can think of a longer or shorter period of time, but this is merely comparative. The difference between 50 and 75 steps a minute in marching is clear to us, but note that we introduce motion and space before we can get a conception of time as a succession of events, but time, in itself, remains elusive.

In time measures we strive for a uniform motion of something and this implies equal spaces in equal times; so we here assume just what we cannot explain, for space is as difficult to define as time. Time cannot be "squared" or used as a multiplier or divisor. Only numbers can be so used; so when we speak of "the square of the time" we mean some number which we have arbitrarily assumed to represent it. This becomes plain when we state that in calculations relating to pendulums, for example, we may use seconds and inches—minutes and feet—or seconds and meters and the answer will come out right in the units which we have assumed. Still more, numbers themselves have no meaning till they are applied to something, and here we are applying them to time, space and motion; so we are trying to explain three abstractions by a fourth! But, happily, the results of these assumptions and calculations are borne out in practical human life, and we are not compelled to settle the deep question as to whether fundamental knowledge is possible to the human mind. Those desiring a few headaches on these questions can easily get them from Kant and Spencer—but that is all they will get on these four necessary assumptions.

Evidently, man began by considering the day as a unit and did not include the night in his time keeping for a long period. "And the evening and the morning were the first day" Gen. 1, 5; "Evening and morning and at noonday," Ps. LV, 17, divides the day ("sun up") in two parts. "Fourth part of a day," Neh. IX, 3, shows another advance. Then comes, "are there not twelve hours in a day," John XI, 9. The "eleventh hour," Matt. XX, 1 to 12, shows clearly that sunset was 12

o'clock. A most remarkable feature of this 12-hour day, in the New Testament, is that the writers generally speak of the third, sixth and ninth hours, Acts II, 15; III, 1; X, 9. This is extremely interesting, as it shows that the writers still thought in quarter days (Neh. IX, 3) and had not yet acquired the 12-hour conception given to them by the Romans. They thought in quarter days even when using the 12-hour numerals! Note further that references are to "hours;" so it is evident that in New Testament times they did not need smaller subdivisions. "About the third hour," shows the mental attitude. That they had no conception of our minutes, seconds and fifth seconds becomes quite plain when we notice that they jumped down from the hour to nowhere, in such expressions as "in an instant—in the twinkling of an eye."

Before this, the night had been divided into three watches, Judges VII, 19. Poetry to this day uses the "hours" and the "watches" as symbols.

This 12 hours of daylight gave very variable hours in latitudes some distance from the equator, being long in summer and short in winter. The amount of human ingenuity expended on time measures so as to divide the time from sunrise to sunset into 12 equal parts is almost beyond belief. In Constantinople, to-day, this is used, but in a rather imperfect manner, for the clocks are modern and run 24 hours uniformly; so the best they can do is to set them to mark twelve at sunset. This necessitates setting to the varying length of the days, so that the clocks appear to be sometimes more and sometimes less than six hours ahead of ours. A clock on the tower at the Sultan's private mosque gives the impression of being out of order and about six hours ahead, but it is running correctly to their system. Hotels often show two clocks, one of them to our twelve o'clock noon system. Evidently the Jewish method of ending a day at sunset is the same and explains the command, "let not the sun go down upon thy wrath," which we might read, do not carry your anger over to another day. I venture to say that we still need that advice.

This simple line of steps in dividing the day and night is taken principally from the Bible because everyone can easily look up the passages quoted and many more, while quotations from books not in general use would not be so clear. Further, the neglect of the Bible is such a common complaint in this country that if I induce a few to look into it a little some good may result, quite apart from the matter of religious belief.

Some Chinese and Japanese methods of dividing the day and night are indicated in Fig. 1. The old Japanese method divides the day into six hours and the night also into six, each hour averaging twice as long as ours. In some cases they did this by changing the rate of the clock, and in others by letting the clock run uniformly and changing the hour marks on the dial, but this will come later when we reach Japanese clocks.

It is remarkable that at the present time in England the "saving daylight" agitation is virtually an attempt to go back to this discarded system. "John Bull," for a long period the time-keeper of the world with headquarters at Greenwich, and during that time the most pretentious clock-maker, now proposes to move his clocks backward and forward several times a year so as to "fool" his workmen out of their beds in the mornings! Why not commence work a few minutes earlier each fortnight while days are lengthening and the reverse when they are shortening?

This reminds me of a habit which was common in Scotland,—"keeping the clock half an hour forward." In those days work commenced at six o'clock, so the husband left his house at six and after a good walk arrived at the factory at six! Don't you see that if his clock had been set right he would have found it necessary to leave at half past five? But, you say he was simply deceiving himself and acting in an unreasonable manner. Certainly, but the average man is not a reasonable being,

nd "John Bull" knows this and is try-
ng to fool the average Englishman.

Now, as to the methods of measur-
ng time, we must use circumstantial
vidence for the pre-historic period. The rising and the going down of the sun—the lengthening shadows, etc., must come first, and we are on safe ground here, for savages still use primitive methods like setting up a stick and marking its shadow so that a party trailing behind can estimate the distance the leaders are ahead by the changed position of the shadow. Men

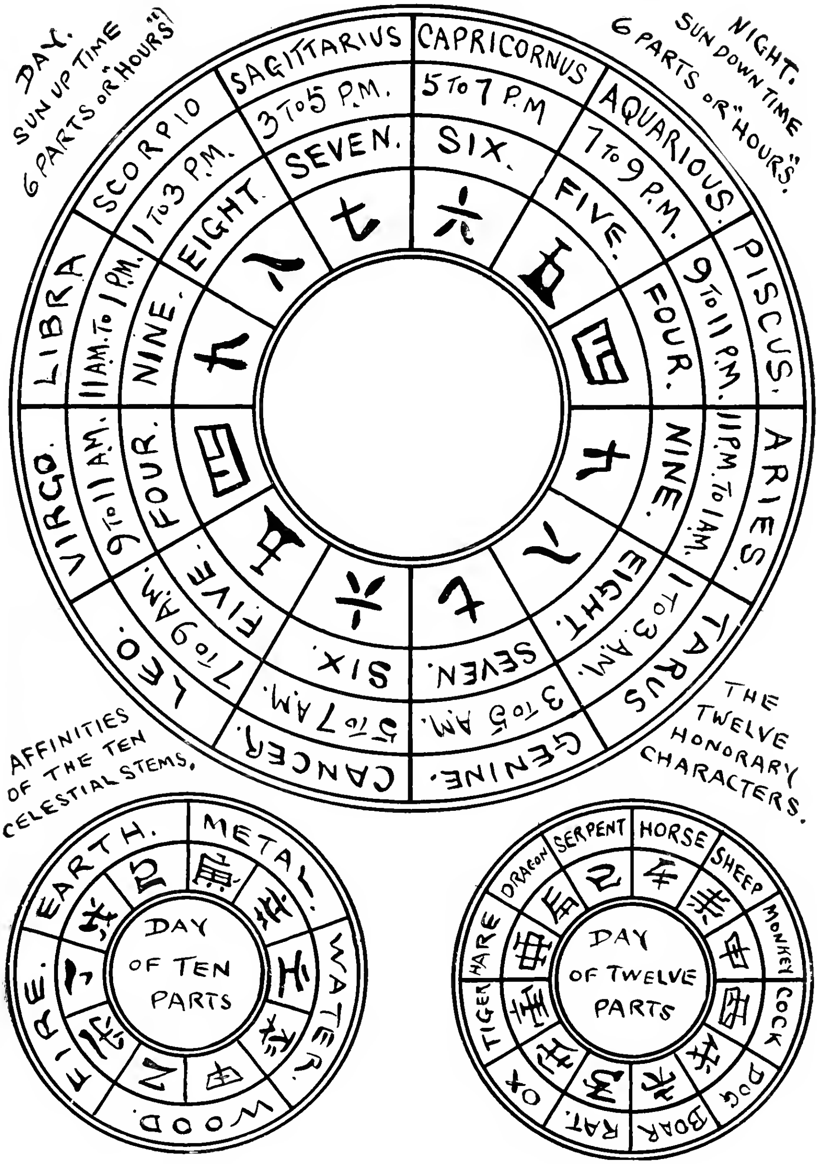


Fig. 1—Interpretation of Chinese and Japanese Methods of Time Keeping

notice their shortening and lengthening shadows to this day. When the shadow of a man shortens more and more slowly till it appears to be fixed, the

observer knows it is noon, and when it shows the least observable lengthening then it is just past noon. Now, it is a remarkable fact that this crude method of determining noon is just the same as "taking the sun" to determine noon at sea. Noon is the time at which the sun reaches his highest point on any given day. At sea this is determined generally by a sextant, which simply measures the angle between the horizon and the sun. The instrument is applied a little before noon and the observer sees the sun creeping upward slower and slower till a little tremor or hesitation appears indicating that the sun has reached his height,—noon. Oh! you wish to know if the observer is likely to make a mistake? Yes, and when accurate local time is important, several officers on a large ship will take the meridian passage at the same time and average their readings, so as to reduce the "personal error." All of which is merely a greater degree of accuracy than that of the man who observes his shadow.

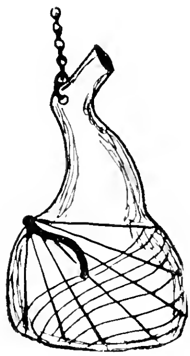


Fig. 2—Portable Bronze Sundial from the Ruins of Herculaneum

The gradual development of the primitive shadow methods culminated in the modern sundial. The "dial of Ahas," Isa. XXXVIII, 8, on which the sun went back 10 "degrees" is often referred to, but in one of the revised editions of the unchangeable word the sun went back 10 "steps." This becomes extremely interesting when we find that in India there still remains an immense dial built with steps instead of hour lines. Figure 2 shows a pocket, or portable sundial taken from the ruins of Herculaneum and now in the Museo National, Naples. It is bronze, was silver plated and is in the form of a ham suspended from the hock joint. From the tail, evidently bent from its original position, which forms the gnomon, lines radiate and across these wavy lines are traced. It is about 5 in. long and 3 in. wide. Being in the corner of a glass case I was unable to get small details, but museum authorities state that names of months are engraved on it, so it would be a good guess that these wavy lines had something to do with the long and short days.

In a restored flower garden, within one of the large houses in the ruins of Pompeii, may be seen a sundial of the Armillary type, presumably in its original position. I could not get close to it, as the restored garden is railed in, but it looks as if the plane of the equator and the position of the earth's axis must have been known to the maker.

Both these dials were in use about the beginning of our era and were covered by the great eruption of Vesuvius in 79 A.D., which destroyed Pompeii and Herculaneum.

Modern sundials differ only in being more accurately made and a few "curiosity" dials added. The necessity for time during the night, as man's life became a little more complicated, necessitated the invention of time machines. The "clepsydra," or water clock, was probably the first. A French writer has dug up some old records putting it back to Hoang-ti 2679 B.C., but it appears to have been certainly in use in China in 1100 B.C., so we will be satisfied with that date. In presenting a subject to the young student it is sometimes advisable to use round numbers to give a simple comprehension and then leave him to find the overlapping of dates and methods as he advances. Keeping this in mind, the following table may be used to give an elementary hint of the three great steps in time measuring:

Shadow time, 2000 to 1000 B. C.

Dials and Water Clocks, 1000 B. C. to 1000 A. D.

Clocks and watches, 1000 to 2000 . D.

I have pushed the gear wheel clocks ıd watches forward to 2000 A.D., as ıey may last to that time, but I have) doubt we will supersede them. At .e present time science is just about ady to say that a time measurer consting of wheels and pinions—a drivg power and a regulator in the form ' a pendulum or balance, is a clumsy ›ntrivance and that we ought to do etter very soon; but more on this ›ped-for, fourth method when we ach the consideration of the motion ı which we base all our time keeping.

It is remarkable how few are aware .at the simplest form of sundial is the :st, and that, as a regulator of our resent clocks, it is good within one or vo minutes. No one need be without "noon-mark" sundial; that is, every ıe may have the best of all dials. Take post or any straight object standing ›lumb," or best of all the corner of building as in Fig. 3. In the case of ıe post, or tree trunk, a stone (shown solid black) may be set in the round; but for the building a line may ten be cut across a flagstone of the otpath. Many methods may be emoyed to get this noon mark, which is mply a north and south line. Viewg the pole star, using a compass (if ıe local variation is known) or the old ethod of finding the time at which ıe shadow of a pole is shortest. But ıe best practical way in this day is to se a watch set to local time and make ıe mark at 12 o'clock.

On four days of the year the sun is ght and your mark may be set at 12 ı these days, but you may use an alanac and look in the column marked nean time at noon" or "sun on merian." For example, suppose on the ight day when you are ready to place our noon mark you read in this ›lumn 11:50, then when your watch ıows 11:50 make your noon mark to ıe shadow and it will be right for all me to come. Owing to the fact that ıere are not an even number of days a year, it follows that on any given :arly date at noon the earth is not at

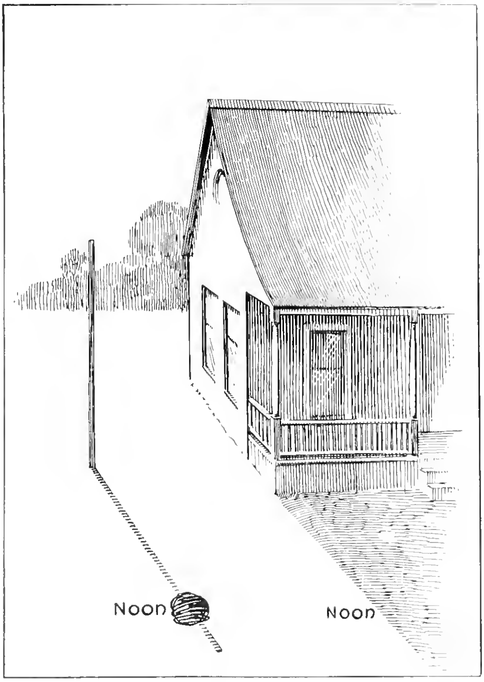


Fig. 3—Noon-Mark Sundials

SUN ON NOON MARK, 1909

Date	Clock Time	Date	Clock Time	Date	Clock Time
Jan.	2...12:04	May	1...11:57	Sept.	30...11:50
"	4...12:05	"	15...11:56	Oct.	3...11:49
"	7...12:06	"	28...11:57	"	6...11:48
"	9...12:07	June	4...11:58	"	10...11:47
"	11...12:08	"	10...11:59	"	14...11:46
"	14...12:09	"	14...12:00	"	19...11:45
"	17...12:10	"	19...12:01	"	26...11:44
"	20...12:11	"	24...12:02	Nov.	17...11:45
"	23...12:12	"	29...12:03	"	22...11:46
"	28...12:13	July	4...12:04	"	25...11:47
Feb.	3...12:14	"	10...12:05	"	29...11:48
"	26...12:13	"	19...12:06	Dec.	1...11:49
Mar.	3...12:12	Aug.	11...12:05	"	4...11:50
"	8...12:11	"	16...12:04	"	6...11:51
"	11...12:10	"	21...12:03	"	9...11:52
"	15...12:09	"	25...12:02	"	11...11:53
"	18...12:08	"	28...12:01	"	13...11:54
"	22...12:07	"	31...12:00	"	15...11:55
"	25...12:06	Sept.	4...11:59	"	17...11:56
"	28...12:05	"	7...11:58	"	19...11:57
Apr.	1...12:04	"	10...11:57	"	21...11:58
"	4...12:03	"	12...11:56	"	23...11:59
"	7...12:02	"	15...11:55	"	25...12:00
"	11...12:01	"	18...11:54	"	27...12:01
"	15...12:00	"	21...11:53	"	29...12:02
"	19...11:59	"	24...11:52	"	31...12:03
"	24...11:58	"	27...11:51		

The above table shows the variation of the sun from "mean" or clock time, by even minutes.

the same place in its elliptical orbit and the correction of this by the leap years causes the equation table to vary in periods of four years. The centennial leap years cause another variation of 400 years, etc., but these variations are less than the error in reading a dial.

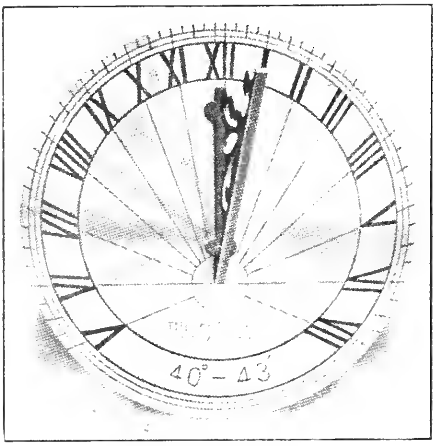


Fig. 4—12-Inch Modern Horizontal Sundial for Latitude 40°—43′

The reason that the table given here is convenient for setting clocks to mean time is that a minute is as close as a dial can be read, but if you wish for greater accuracy, then the almanac, which gives the "equation of time" to a second for each day, will be better. The reason that these noon-mark dials are better than ordinary commercial dials is that they are larger, and still further, noon is the only time that any dial is accurate to sun time. This is because the sun's rays are "refracted" in a variable manner by our atmosphere, but at noon this refraction takes place on a north and south line, and as that is our noon-mark line the dial reads

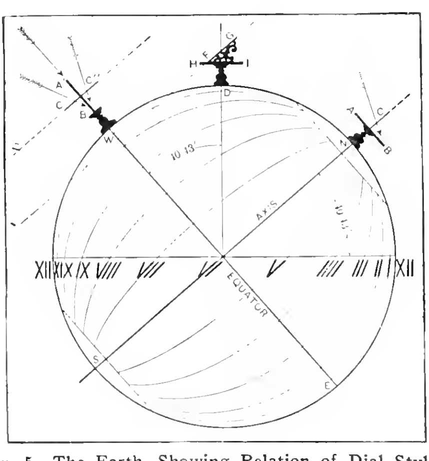


Fig. 5—The Earth, Showing Relation of Dial Styles to Axis

correctly. So, for setting clocks, the corner of your house is far ahead of the most pretentious and expensive dial. In Fig. 4 is shown a modern horizontal dial without the usual confusing "ornamentation," and in Fig. 5 it is shown set up on the latitude of New York City for which it is calculated. This shows clearly why the edge FG of the style which casts the shadow must be parallel to the earth's axis and why a horizontal dial must be made for the latitude of the place where it is set up. Figure 6 is the same dial only the lines are laid out on a square dial plate, and

Fig. 6—Modern Sundial Set Up in Garden

it will give your young scientific readers a hint of how to set up a dial in the garden. In setting up a horizontal dial, consider only noon and set the style, or 12 o'clock line, north and south as described above for noon-mark dials.

A whole issue of Popular Mechanics could be filled on the subject of dials and even then only give a general outline. Astronomy, geography, geometry, mathematics, mechanics, as well as architecture and art, come in to make "dialing" a most charming scientific and intellectual avocation.

During the night and also in cloudy 'eather the sundial was useless and 'e read that the priests of the temples nd monks of more modern times went out to observe the stars" to make guess at the time of night. The most rominent type after the shadow deices was the "water clock" or "clepsyra," but many other methods were sed, such as candles, oil lamps and in omparatively late times, the sand lass. The fundamental principle of all 'ater clocks is the escape of water from vessel through a small hole. It is vident that such a vessel would empty self each time it is filled in very nearly ie same time. The reverse of this has een used as shown in Fig. 7, which presents the "time-boy" of India. He ts in front of a large vessel of water nd floats a bronze cup having a small ole in its bottom in this large vessel, nd the leakage gradually lowers this ıp till it sinks, after which he fishes up and strikes one or more blows on as a gong. This he continues and a ıde division of time is obtained,—hile he keeps awake!

The most interesting of all water ocks is undoubtedly the "copper jars ropping water," in Canton, China, here I saw it in 1897. Referring to ie simple line sketch, which I make om memory, Fig. 8, and reading four hinese characters downwards the anslation is "Canton City." To the ft and still downwards,—"Hon-woo--low," which is,—"Copper jars dropng water." Educated Chinamen inırm me that it is over 3,000 years old

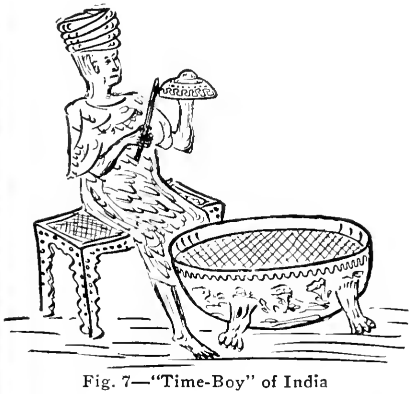


Fig. 7—"Time-Boy" of India

and had a weather vane. As they speak of it as "the clock of the street arch" this would look quite probable; since the little open building, or tower in

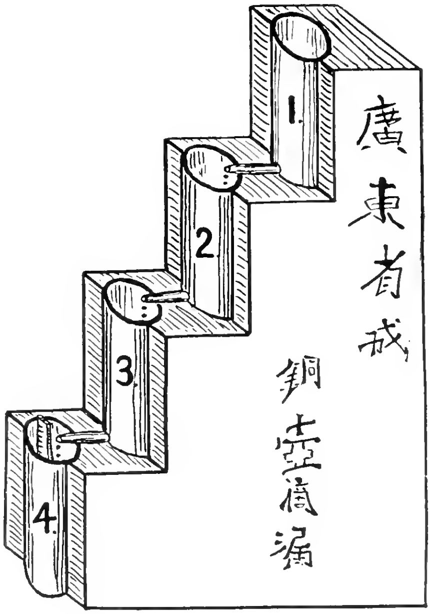


Fig. 8—"Hon-woo-et-low" or "Copper Jars Dropping Water"—Canton, China

which it stands is higher than surrounding buildings. It is, therefore, reasonably safe to state that the Chinese had a *weather and time station* over 1,000 years before our era. It consists of four copper jars partially built in masonry forming a stair-like structure. Commencing at the top jar each one drops into the next downward till the water reaches the solid bottom jar. In this lowest one a float, "the bamboo stick," is placed and indicates the height of the water and thus in a rude way gives the time. It is said to be set morning and evening by dipping the water from jar 4 to jar 1, so it runs 12 hours of our time. What are the uses of jars 2 and 3, since the water simply enters them and drips out again? No information could be obtained, but I venture an explanation and hope the reader can do better, as we are all of a family and there is no jealousy. When the top jar is filled for a 12-hour run it would drip out too fast during the first six hours

and too slow during the second six hours, on account of the varying "head" of water. Now, the spigot of jar 2 could be set so that it would gain water during the first six hours, and lose during the second six hours and thus equalize a little by splitting the error of jar 1 in two parts. Similarly, these two errors of jar 2 could be again split by jar 3 making four small variations in lowest jar, instead of one large error in the flow of jar 1. This could be extended to a greater number of jars, another jar making eight smaller errors, etc., etc. But I am inclined to credit our ancient Chinese inventor with the sound reasoning that a human attendant, being very fallible and limited in his capacity, would have all he could properly do to adjust four jars, and that his record would average better than it would with a greater number. Remember, this man lived thousands of years before the modern mathematician who constructed a bell-shaped vessel with a small hole in the bottom, and proportioned the varying diameter in such a manner that in emptying itself the surface of the water sank equal distances in equal times. The sand glass, Fig. 9, poetically called the "hour glass," belongs to the water-clock class and the sand flows from one bulb into the other, but it gives no subdivisions of its period, so if you are using one running an hour it does not give you the half hour. The sand glass is still in use by chairmen, and when the oldest inhabitant gets on his feet, I always advise setting a 20-minute glass "on him."

Fig. 9—Modern Sand Glass or "Hour Glass"

In the "Tower of the Winds" at Athens, Greece (Fig. 10), we have a later "weather bureau" station. It is attributed to the astronomer Andronicos, and was built about 50 B. C. It is octagonal in plan and although 27 ft in diameter and 44 ft. high, it looks like a sentry box when seen from one of the hills of Athens. It had a bronze weather vane and in later times sun dials on its eight sides, but all these are gone and the tower itself is only a dilapidated ruin. In making the drawing for this cut, from a photograph of the tower, I have sharpened the weathered and chipped corners of the stones so as to give a view nearly like the structure as originally built; but nothing is added. Under the eaves it has eight allegorical sculptures, representing wind and weather. Artists state that these sculptures are inferior as compared with Grecian art of an older period. But the most interesting part is inside, and here we find curious passages cut in solid stone, and sockets which look as if they had contained metal bearings for moving machinery. Circumstantial evidence is strong that it contained a complicated water clock

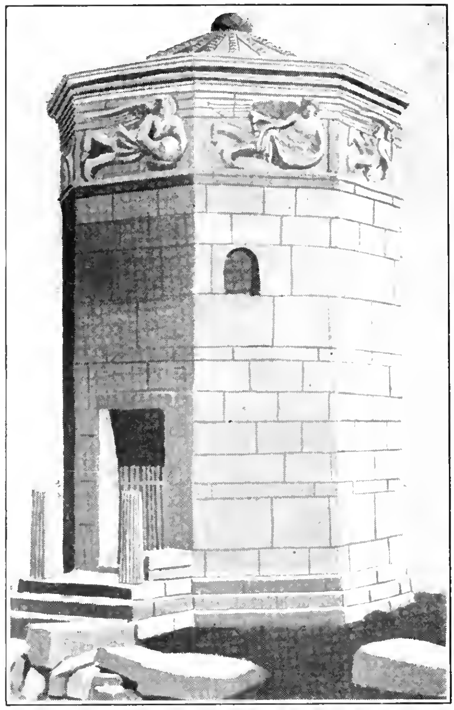


Fig. 10—"Tower of the Winds"—Athens, Greece

which could have been kept running with tolerable accuracy by setting it daily to the dials on the outside. Probably during a few days of cloudy weather the clock would "get off quite a little," but business was not pressing in those days. Besides, the timekeeper would swear by his little water wheel, anyway, and feel safe, as there was no higher authority wearing an American watch.

Some very interesting engravings of Japanese clocks and a general explanation of them, as well as a presentation of the Japanese mental attitude towards "hours" and their strange method of numbering them may be expected in the next chapter.

CHAPTER II

JAPANESE CLOCKS

Chinese and Japanese divisions of the day.—Hours of varying length.—Setting clocks to length of daylight.—Curved line dials.—Numbering hours backwards and strange reasons for same.—Daily names for sixty day period.—Japanese clock movements practically Dutch.—Japanese astronomical clock.—Decimal numbers very old Chinese.—Original vertical dials founded on "bamboo stick" of Chinese clepsydra. —Mathematics and superstition.—Mysterious disappearance of hours 1, 2, 3.—Eastern mental attitude towards time.—Japanese methods of striking hours and half hours.

CHAPTER II

The ancient methods of dividing day and night in China and Japan become more hazy as we go backwards and the complications grow. The three circles in Fig. 1 (Chapter 1) are all taken from Japanese clocks, but the interpretation has been obtained from Chinese and Japanese scholars. The Japanese obtained a great deal from the Chinese, in fact nearly everything relating to the ancient methods of time keeping and the compiling of calendars. I have not been able to find any Chinese clocks constructed of wheels and pinions, but have a number of Japanese. These have a distinct resemblance to the earlier Dutch movements, and while made in Japan, they are practically Dutch, so far as the "works" are concerned, but it is easy to see from the illustrations that they are very Japanese in style and ornamentation. The Dutch were the leaders in opening Japan to the European nations and introduced modern mathematics and clocks from about 1590 A. D. The ancient mathematics of Japan came largely from China through Corea. In Fig. 11 are given the Japanese figures beside ours, for the reader's use as a key. The complete day in Japan was divided into twice six hours; that is, six for daylight and six for night, and the clocks are set, as the days vary in length, so that six o'clock is sunrise and sunset. The hour numerals on Fig. 12 are on little plates which are movable, and are shown set for a long day and a short night.

一	1
二	2
三	3
四	4
五	5
六	6
七	7
八	8
九	9
十	10
十一	11
十二	12

Fig. 11

In Fig. 13 they are set for short days and long nights. The narrow plates shown in solid black are the half-hour marks. In this type the hand is stationary and always points straight upward. The dial rotates, as per arrow, once in a full day. This style of dial is shown on complete clocks, Fig. 14 being a weight clock and Fig. 15 a spring clock with chain and fusee. The hours are 9 to 4 and the dials rotate to make them read backwards. The six hours of daylight are 6, 5, 4, 9, 8, 7, 6 and the same for night, so these hours average twice as long as ours. Note that nine is mid-day and mid-night, and as these do not change by long and short days they are stationary on the dial, as you

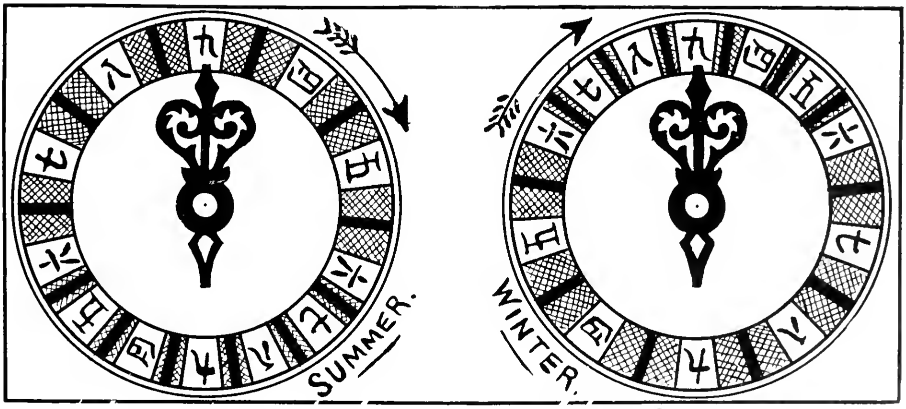


Fig. 12 Fig. 13.

Japanese Dials Set for Long and Short Days

can easily see by comparing Figs. 12 and 13, which are the same dial set for

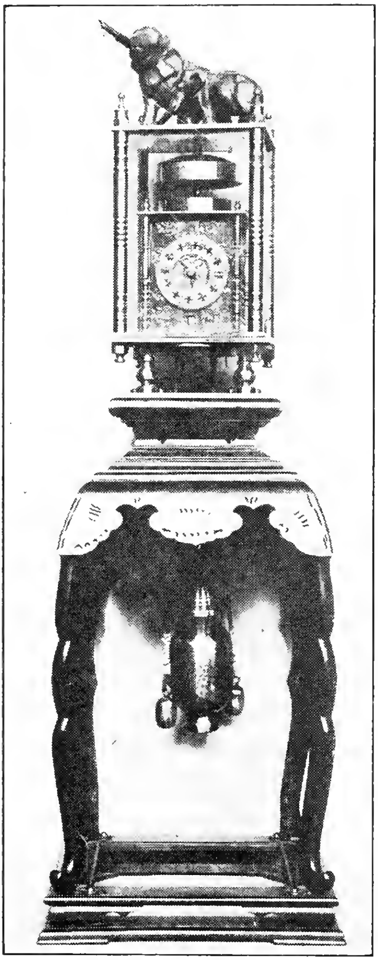


Fig. 14—Japanese Striking Clock with Weight and Short Pendulum

different seasons. Between these extremes the dial hours are set as often as the owner wishes; so if he happens to correspond with our "time crank" he will set them often and dispute with his neighbors about the time. Figure 16 shows a clock with the hour numerals on a vertical series of movable plates and it is set for uniform hours when day and night are equal at the equinox. The ornamental pointer is fastened to the weight through the vertical slit, plainly visible in illustration, and indicates the time as it descends. This clock is wound up at sunset, so the six on the top of the dial is sunset the same as the six on the bottom. Figure 17 shows how this type of dial is set for long and short days and explains itself, but will become plainer as we proceed. This dial is virtually a continuation of the old method of marking time by the downward motion of the water in the clepsydras and will be noticed later.

Figure 18 represents a clock which is a work of art and shows great refinement of design in providing for the varying lengths of days. The bar lying across the dial is fastened to the weight through the two slits running the whole length of the dial. On this cross bar is a small pointer, which is movable by the fingers, and may be set to any one of the thirteen vertical lines. The numerous characters on the top space of dial indicate the dates on which the pointer is to be set. This clock is wound up at sunset, and it is easy to see that as the little pointer is set towards the right, the night hours at the top of the dial become shorter and the day hours longer on the lower part. The left edge of the dial gives the hours, reading down-

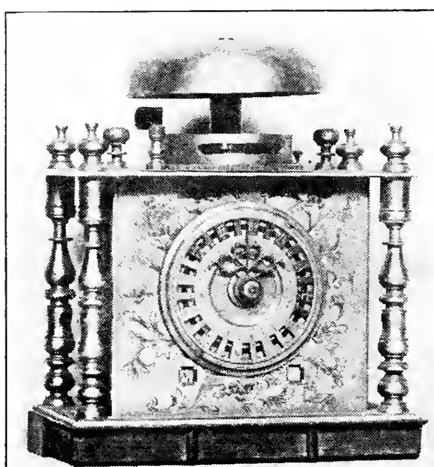


Fig. 15—Japanese Striking Clock with Spring, Fusee and Balance

wards, and as the pointer touches any one of the curved lines the hour is

ad at the left-hand end. The curved es formed of dots are the half-hours. ne right-hand edge of the dial has e "twelve horary characters" which ll be explained later. For dividing e varying days into six hours' sun-ine it would be difficult to think of more artistic and beautiful invention an this. It is a fine example of great genuity and constant trouble to op-ate a system which is fundamentally rong according to our method of uni-rm hours at all seasons. Clocks iving these curved lines for the vary-g lengths of days—and we shall find em on circular dials as we go on—ust be made for a certain latitude, nce the days vary more and more as ou go farther from the equator. This ill become plain when you are re-inded that a Japanese clock at the uator would not need any adjust-ent of hour numerals, because the iys and nights are equal there all the ear. So after such infinite pains in rming these curved lines the clock only good in the latitude for which was made and must not be carried orth or south! Our clocks are correct om pole to pole, but all clocks must set to local time if they are carried ist or west. As this is a rather scinating phase of the subject it ight be worth pointing out that if ou go north till you have the sun up r a month in the middle of summer—id there are people living as far up that—the Japanese system would ecome absurd and break down; so ere is no danger of any of our polar peditions carrying Japanese clocks.

Figure 19 shows a very fine clock which the dial is stationary and the ind moves just as on our dials. This our hand corresponds to the single ind of the old Dutch clocks. When e Japanese reached the point of con-dering the application of minute and cond hands to their clocks they found at these refinements would not fit eir old method and they were com-elled to lay aside their clocks and ke ours. On this dial, Fig. 19, nine noon, as usual, and is on top side of al. Hand points to three quarters past *seven*, that is, a quarter to *six*, near sunset. Between the bell and the

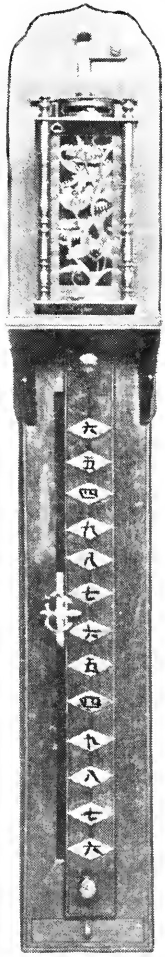


Fig. 16—Japanese Clock with Vertical Dial, Weight and Balance.

Fig. 18—Japanese Clock with Vertical Dial Having Curved Lines, Weight and Balance.

top of the clock body two horizontal balances, having small weights hung on them, are plainly shown, and the clock has two verge escapements—one connected with each balance, or "foliot." Let us suppose a long day coming to a close at sunset, just as the hand indicates. The upper balance, which is the slow one, has been swinging backwards and forwards measuring the long hours of the day. When the clock strikes six, at sunset, the top balance is thrown out of action and the lower one, which is the fast one,

is thrown into action and measures the short night hours. At sunrise this is

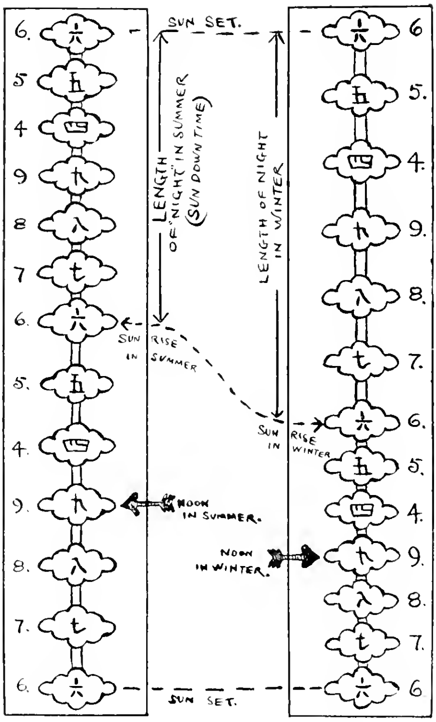


Fig. 17—Japanese Vertical Dials

thrown out and the top one in again to measure the next day's long hours. As the days vary in length, the balances, or foliots, can be made to swing faster or slower by moving the weights inwards or outwards a notch or two. The balance with small weights for regulation is the oldest known and was used in connection with the verge escapement, just as in this clock, by the Dutch about 1364. All the evidence I can find indicates that the Japanese clocks are later than this date. In design, ornamentation and methods for marking varying days, however, the Japanese have shown great artistic taste and inventiveness. It is seen that this dial in addition to the usual six hours, twice over, has on the outside circle of dial, the "twelve horary branches" called by the Japanese the "twelve honorary branches," thus indicating the whole day of twelve Japanese hours, six of them for day and six for night. By this mear they avoided repeating the same hou for day and night. When it pointed out that these "twelve horar branches" are very old Chinese, w are not in a position to boast abo our twenty-four hour system, becau these branches indicate positive whether any given hour is day or nigh When we print a time table in th twenty-four hour system so as to g rid of our clumsy A. M. and P. M., w are thousands of years behind the Ch nese. More than that, for they g the matter right without any suc pressure as our close running trai have brought to bear on us. The branches have one syllable names a the "ten celestial stems" have also o syllable names, all as shown on Fi 20. Refer now to Fig. 21 where tw disks are shown, one having th "twelve horary branches" and th other the "ten celestial stems." The disks are usually put behind the di so that one "branch" and one "stem can be seen at the same time throug two openings. The clock moves the disks one step each night, so that new pair shows each day. Runnin in this manner, step by step, you w find that it takes sixty moves, that sixty days, to bring the same pa around again. Each has a sing syllable name, as shown on Fig. 2 and we thus get sixty names of tw syllables by reading them together the left. The two openings may b seen in the dials of Figs. 15 and 1 So the Japanese know exactly wh day it is in a period of sixty whic they used in their old calendars. The were used by the Chinese over fo thousand years ago as the names a cycle of sixty years, called the "se agenary." The present Chinese yea 4606 is YU-KI which means the yea 46 of the 76th "sexagenary." That i $76 \times 60 + 46 = 4{,}606$. In Fig. 20, w read TSU-KIAH, or the first year. you will make two disks like Fig. 2 and commence with TSU-KIAH an move the two together you will com to YU-KI on the 46th move. Bu there is another way which you migh

xe better, thus: Write the twelve branches," or syllables, straight downards, continuously five times; close the right, write the ten "stems" six mes. Now you have sixty words of vo syllables and the 46th, counting ownwards, will be YU-KI. Besides, is method gives you the whole sixty ames of the "sexagenary" at one view. lways read *left,* that is, pronounce ie "stem" syllable first.

Calendars constitute a most intersting and bewildering part of time ieasuring. We feel that we have seted the matter by determining the ength of the year to within a second f time, and keeping the dates corectly to the nearest day by a leap year very fourth and every fourth century, stablished by Pope Gregory XIII in 582, and known as the "Gregorian alendar." In simple words, our "alianac" is the "Gregorian." We are the habit of saying glibly that any ear divisible by four is a leap year, ut this is far from correct. Any year eaving out the *even hundreds,* which s divisible by four is a leap year. *Even hundreds* are leap when divisible y four. This explains why 1900 was common year, because *19 hundreds* s not divisible by four; 2000 will be leap because *20 hundreds* is divisible y four; therefore 2100, 2200 and 300 will be common years and 2400 leap, etc., to 4000 which must be iade common, to keep things straight, n spite of the fact that it is divisible y four both in its hundreds and thouands. But for practical purposes, durng more than two thousand years to ome, we may simplify the rule to: *Years* and *even hundreds* divisible by our are leaps. But great confusion till exists as a result of several counries holding to their own old methods. The present Chinese year has 384 days, 3 months and 13 full moons. Compared with our 1909 it begins on Janary 21st and will end on February 8, 910. Last year the China-Japan calendar had 12 months, or moons, but s that is too short they must put in n extra every thirtieth month. We nly allow the error to reach one day and correct it with our leap years, but they are not so particular and let the

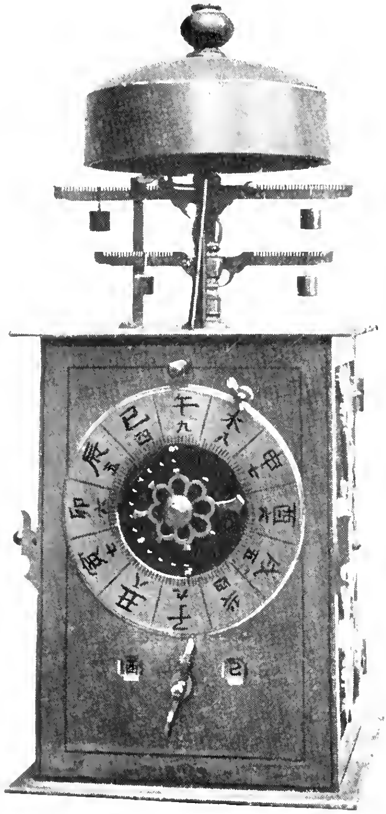


Fig. 19—Japanese Striking Clock with Two Balances and Two Escapements; Dial Stationary, Hand Moves

error grow till they require another "moon." The Old Testament is full of moons, and even with all our "modernity" our "feasts" and holy days are often "variable" on account of being mixed up with moons. In Japan the present year is the 42nd of Meiji, that is, the 42nd of the present Emperor's reign. The present is the Jewish 5669. These and others of varying lengths overlap our year in different degrees, so that in trade matters great confusion exists. The Chinese and Japanese publish a trade almanac in parallel columns with ours to avoid this. It is easy to say that we ought to have a uniform calendar all over the world, but the same remark applies just

as much to money, weights, measures, and even to language itself. Finally, the difficulty consists in the facts that

子	TSU	1	甲	KIAH	1
丑	CHOU	2	乙	YIN.	2
寅	YIN.	3	丙	PING.	3
卯	MAO	4	丁	TING.	4
辰	SHEN	5	戊	WU.	5
巳	SSU.	6	己	KI.	6
午	WU.	7	庚	KENG.	7
未	WEI.	8	辛	SIN.	8
申	SHEN.	9	壬	JEN.	9
酉	YU.	10	癸	KWEI.	10
戌	SUH.	11			
亥	HAI.	12			

Fig. 20—Key to "12 Horary Branches" and "10 Celestial Stems"

there are not an even number of days in a year—or in a moon—or moons in a year. "These many moons" is a survival in our daily speech of this old method of measuring by moons. Just a little hint as to the amount of superstition still connected with "new moon" will be enough to make clear the fact that we are not yet quite so "enlightened" as we say we are. While our calendar, or almanac, may be considered as final, we must remember that custom and religion are so mixed up with the matter in the older countries of the East that they will change very slowly. Strictly, our "era" is arbitrary and Christian; so we must not expect nations which had some astronomical knowledge and a working calendar, thousands of years before us, to change suddenly to our "upstart" methods.

In Fig. 22 we have the dial of a very complicated astronomical clock. This old engraved brass dial did not photograph well, so I made a copy by hand to get clean lines. Commencing at the centre, there is a small disk, B, numbered from 1 to 30, giving days of the moon's age. The moon rises at A and sets at AA, later each day, of course. Her age is shown by the number she touches on disk B, as this disk advances on the moon one number each day. Her phases are shown the motion of a black disk over h face; so we have here three motio for the moon, so differentiated as show *phase, ascension* and *age*. St further, as she is represented on t dial when below the horizon, it c be seen when she will rise, and "moo light" parties may be planned. Ju outside the moon's course is an a nulus having Japanese numbers 1 12, indicating months. Note the r curring character dividing the mont in halves, which means "middle," a is much used. If you will careful read these numbers you will find character where *one* would come; th means "beginning" or "primary" a is often used instead of one. The clo hand is the heavy arrow and swee the dial once in a whole day, sar direction as our clocks. This circ of the months moves along with t hand, but a little faster, so as to ga one number in a month. As shown the figure it is about one week into t sixth month. Next outward is t broad band having twelve curved lin for the hours ending outwardly in ring divided into 100 parts, marke off in tens by dots. These curved lin are numbered with the Japanese n merals for hours which you must no be able to read easily. These hou lines, and the dotted lines for ha hours, are really the same as the sim lar lines on Fig. 18 which you no understand. As the hand sweeps t

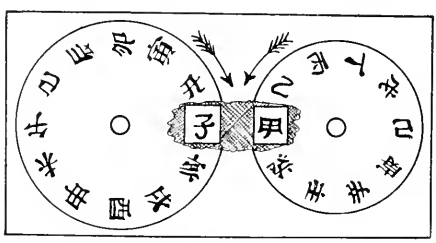


Fig. 21—"12 Horary Branches" and "10 Celestial Stems" as Used in Clocks

dial daily it automatically moves out ward a little each day, so it shorten the nights and lengthens the days just as previously explained for Fig 18. But there is one difference, fo you will notice that the last nigh

our, on which the arrow hand now tands, is longer than the other night ours before it, and that it is divided nto *three* by the dotted lines. The last ay hour, on ne left of dial, s also long nd divided nto *three* That is, while ll the dials reviously described have qual hours or any given ay, or night, his dial has a *ist long hour* n each case, livided into hree instead f the usual alf-hours. This is a curious and intersting point aving its origin long before locks. In the early days of the clepsyra in China, a certain time was allowed o dip up the water from the lowest jar, ach morning and evening about five 'clock of our time, see Fig. 8 (Chaper 1). During this operation the lepsydral was not marking time, and he oriental mind evidently considered in some sense outside of the regular ours, and like many other things was etained till it appeared absurdly on ne earlier clocks. This wonderful eat of putting an interval between wo consecutive hours has always been npossible to modern science; yet President Roosevelt performed it asily in his "constructive" interregum! Referring to the Canton clepydra, Fig. 8, we find that the float, or bamboo stick," was divided into 100 arts. At one season 60 parts for the ay and 40 parts for the night, gradally being changed to the opposite or short days. The day hours were eaten on a drum and the night hours lown on a trumpet.

Later the hour numerals were made movable on the "bamboo stick." This is virtually a vertical dial with movable hour plates, so their idea of time measuring at that date, was of something moving up or down. This was put on the first clocks by the Japanese; so that the dial of Fig. 16 is substantially the float of the Chinese clepsydra. Further, in this "bamboo stick" of 100 parts, we have our present system of decimal numbers, so we can afford to be a little modest here too. Before leaving Fig. 22 note the band, or annulus, of stars which moves with the month circle. I cannot make these stars match our twelve signs of the Zodiac, but as I have copied them carefully the reader can try and make order out of them. The extreme outer edge of the dial is divided into 360 parts, the tens being emphasized, as in our decimal scales.

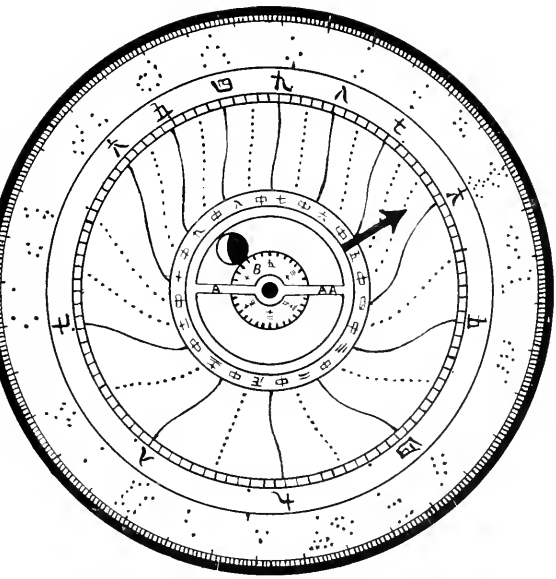


Fig. 22—Dial of Japanese Astronomical Clock

As we are getting a little tired of these complicated descriptions, let us branch off for a few remarks on some curiosities of Eastern time keeping. They evidently think of an hour as a *period of time* more specifically than we do. When we say "6 o'clock" we mean a point of time marked by the striking of the clock. We have no names for the hour periods. We must say "from 5 to 6" or "between 5 and 6" for an hour period. The "twelfth hour" of the New Testament, I understand to mean a whole hour ending at sunset; so we are dealing with an oriental attitude of mind towards time. I think we get that conception

nearly correct when we read of the "middle watch" and understand it to mean *during* the middle third of the night. Secondly, why do the Japanese use no 1, 2, 3 on their dials? These numbers were sacred in the temples and must not be profaned by use on clocks, and they mentally deducted these from the clock hours, but ultimately became accustomed to 9, 8, 7, 6, 5, 4. Thirdly, why this reading of the hours backwards? Let us suppose a toiler commencing at sunrise, or six. When he toiled one hour he felt that there was one less to come and he called it five. This looks quite logical, for the diminishing numbers indicated to him how much of his day's toil was to come. Another explanation which is probably the foundation of "secondly" and "thirdly" above, is the fact that mathematics and superstition were closely allied in the old days of Japan. If you take the numbers 1 to 6, Fig. 23, and multiply them each into the uncanny "yeng number," or nine, you will find that the last digits, reading downwards, give 9, 8, 7, 6, 5, 4. Stated in other words: When 1 to 6 are multiplied into "three times three" the last figures are 9, 8, 7, 6, 5, 4, and *1, 2, 3, have disappeared;* so the common people were filled with fear and awe. Some of the educated, even now, are mystified by the strange results produced by using three and nine as factors, and scientific journals often give space to the matter. We know that these results are produced by the simple fact that nine is one less than the "radix" of our decimal scale of numbers. Nine is sometimes called the "indestructible number," since adding the digits of any of its powers gives an even number of nines. But in those days it was a mystery and the common people feared the mathematicians, and I have no doubt the shrewd old fellows took full advantage of their power over the plebeians. In Japan, mathematics was not cleared of this rubbish till about 700 A. D

On the right-hand side of Fig. 23 are given the animal names of the hours, so the day and night hours could not be mistaken. In selectin the *rat* for night and the *horse* for da they showed good taste. Their for

1 X 9 = 9	九 RAT MIDNIGHT
2 X 9 = 18	八 OX. 2AM
3 X 9 = 27	七 TIGER 4AM
4 X 9 = 36	六 HARE 6AM
5 X 9 = 45	五 DRAGON 8AM
6 X 9 = 54	四 SNAKE 10AM
1 X 9 = 9	九 HORSE NOON
2 X 9 = 18	八 SHEEP 2P.M.
3 X 9 = 27	七 MONKEY 4P.M.
4 X 9 = 36	六 COCK 6P.M.
5 X 9 = 45	五 DOG 8P.M.
6 X 9 = 54	四 BOAR 10P.M.

Fig. 23—Use of "Yeng Number" and Animal Names of Hours

noon was "before horse" and the afternoon "after horse." Japane clocks are remarkable for variety. looks as if they were always made order and that the makers, probab urged by their patrons, made extren efforts to get in wonderful motio and symbols relating to astronomy ar astrology. Anyone examining abo fifty of them would be likely to co clude that it was almost hopeless understand them all. Remember, th is the old Japanese method. Near all the clocks and watches I saw Japan were American. It will now l necessary to close this chapter with few points on the curious striking Japanese clocks.

In those like Figs. 14, 15, 19, tl bell and hammer can be seen. In tl type of Fig. 16, the whole strikin mechanism is in the weight. In fac the striking part of the clock is tl weight. On each of the plates, havi the hour numerals, Fig. 16, a pin pr jects inwards and as the weight co taining the striking mechanism, d scends, a little lever touches these a lets off the striking just when tl pointer is on the hour numeral. Kee ing this in mind, it is easy to see th the clock will strike correctly wh the hour is indicated by the point

) matter how the hour plates are set r long or short days. Similar pins 'oject inwards from movable plates ı Figs. 12, 13, 14, 15, so they strike ›rrectly as each hour plate comes to e top just under the point of the xed hand. In Fig. 19, the striking is t off by a star wheel just as in old utch clocks. Clocks like Figs. 18- : do not strike. In all cases the hours e struck backwards, but the half- ›urs add another strange feature. he *odd* numbered hours, 9, 7, 5, are llowed by one blow at the half hour; ıd the *even* hours, 8, 6, 4 by two blows, · stated altogether—

$$9_1 \quad 8_2 \quad 7_1 \quad 6_2 \quad 5_1 \quad 4_2.$$

ere the large figures are the hours ıd the small ones the half-hours. Only one bell is used, because there being no one and two among the hours, the half-hours cannot be mistaken. This is not all, for you can tell what half hour it is within two hours. For example, suppose you know approximately that it is somewhere between 9 and 7 and you hear the clock strike 2, then you know it is half past 8. See the large and small figures above. This is far superior to our method of one at each half-hour.

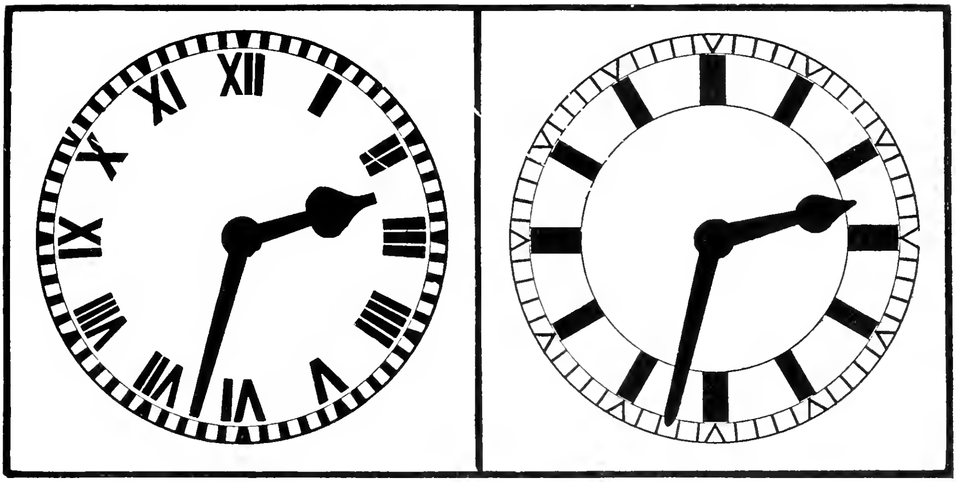
By our method the clock strikes *one* three times consecutively, between 12 and 2 o'clock and thus mixes up the half hours with one o'clock. Some interesting methods of striking will be explained in the third chapter when we deal with modern time keeping.

CHAPTER III

MODERN CLOCKS

DeVick's clock of 1364.—Original "verge" escapement.—"Anchor" and "dead beat" escapements.—"Remontoir" clock.—The pendulum.—Jeweling pallets.—Antique clock with earliest application of pendulum.—Turkish watches.—Correct designs for public clock faces.—Art work on old watches.—Twenty-four hour watch.—Syrian and Hebrew hour numerals.—Correct method of striking hours and quarters.—Design for twenty-four hour dial and hands.—Curious clocks.—Inventions of the old clockmakers.

CHAPTER III



Public Dial by James Arthur — Dial of Philadelphia City Hall Clock

Fig. 24

Modern clocks commence with De Vick's of 1364 which is the first un- questioned clock consisting of toothed vheels and containing the funda- nental features of our present clocks. References are often quoted back to ibout 1000 A. D., but the words trans- ated "clocks" were used for bells and lials at that date; so we are forced to consider the De Vick clock as the first ill more evidence is obtained. It has been pointed out, however, that this clock could hardly have been invented ill at once; and therefore it is probable hat many inventions leading up to it have been lost to history. The part of a clock which does the ticking is called he "escapement" and the oldest form known is the "verge," Fig. 25, the date of which is unknown, but safely 300 years before De Vick. The "foliot" s on the vertical verge, or spindle, vhich has the pallets A B. As the oliot swings horizontally, from rest to rest, we hear one tick, but it requires wo of these single swings, or two icks, to liberate one tooth of the es- ape wheel; so there are twice as many ticks in one turn of the escape wheel as it has teeth. We thus see that an es- capement is a device in which some- thing moves back and forth and allows the teeth of an "escape wheel" to es- cape. While this escapement is, in some respects, the simplest one, it has always been difficult to make it plain in a drawing, so I have made an effort to explain it by making the side of the wheel and its pallet B, which is nearest the eye, solid black, and farther side and its pallet A, shaded as in the figure. The wheel moves in the direc- tion of the arrow, and tooth D is very near escaping from pallet B. The tooth

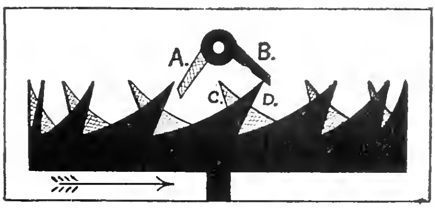


Fig. 25—Verge Escapement

C on the farther side of wheel is mov- ing left, so it will fall on pallet A, to be

in its turn liberated as the pallets and foliot swing back and forth. It is easy

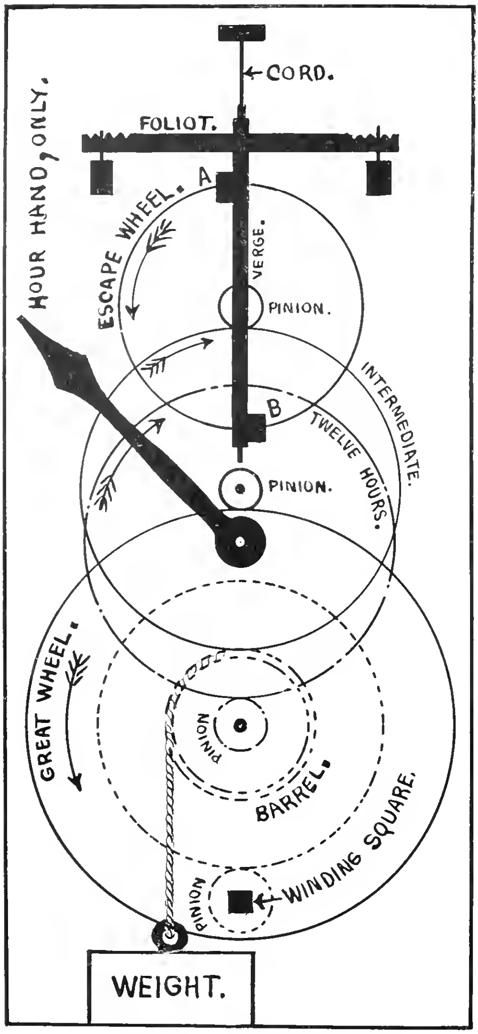


Fig. 26—De Vick's Clock of 1364

to see that each tooth of the wheel will give a little push to the pallet as it escapes, and thus keep the balance swinging. This escapement is a very poor time-keeper, but it was one of the great inventions and held the field for about 600 years, that is, from the days when it regulated bells up to the "onion" watches of our grandfathers. Scattered references in old writings make it reasonably certain that from about 1,000 to 1,300 bells were struck by machines regulated with this verge escapement, thus showing that the striking part of a clock is older than the clock itself. It seems strange to us to say that many of the earlier clocks were strikers, only, and had no dials or hands, just as if you turned the face of your clock to the wall and depended on the striking for the time. Keeping this action of the verge escapement in mind we can easily understand its application, as made by De Vick, in Fig. 26 where I have marked the same pallets A B. A tooth is just escaping from pallet B and then one on the other side of the wheel will fall on pallet A. Foliot verge and pallets form one solid piece which is suspended by a cord, so as to enable it to swing with little friction. For the purpose of making the motions very plain I have left out the dial and framework from the drawing. The wheel marked "twelve hours," and the pinion which drives it, are both outside the frame, just under the dial, and are drawn in dash and dot. The axle of this twelve-hour wheel goes through the dial and carries the hand, which marks hours only. The winding pinion and wheel, in dotted lines, are inside the frame. Now follow the "great wheel"—"intermediate"—"es

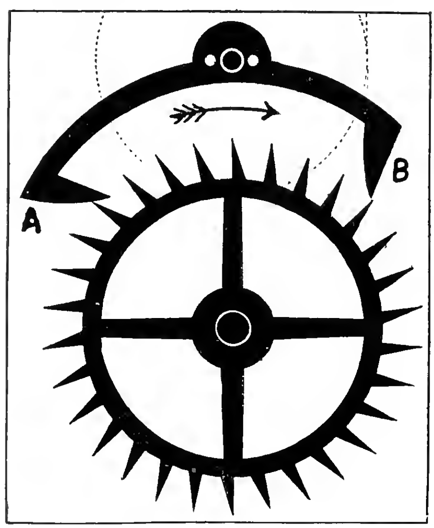


Fig. 27—Anchor Escapement

cape wheel" and the two pinions, all in solid lines, and you have the "train"

which is the principal part of all clocks. This clock has an escapement, wheels, pinions, dial, hand, weight, and winding square. We have only added the pendulum, a better escapement, the minute and second hands in over 500 years! The "anchor" escapement, Fig. 27, came about 1680 and is attributed to Dr. Hooke, an Englishman. It gets its name from the resemblance of the pallets to the flukes of an anchor. This anchor is connected to the pendulum and as it swings right and left, the teeth of the escape wheel are liberated, one tooth for each two swings from rest to rest, the little push on the pallets A B, as the teeth escape, keeping the pendulum going. It is astonishing how many, even among the educated, think that the pendulum drives the clock! The pendulum must always be driven by some power.

This escapement will be found in nearly all the grandfather clocks in connection with a seconds pendulum. It is a good time-keeper, runs well, wears well, stands some rough handling and will keep going even when pretty well covered with dust and cobwebs; so it is used more than all the numerous types ever invented. Figure

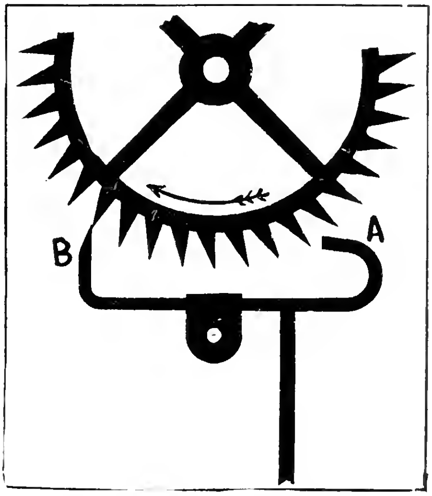


Fig. 28—American Anchor Escapement

28 gives the general American form of the "anchor" which is made by bending a strip of steel; but it is not the best form, as the acting surfaces of the

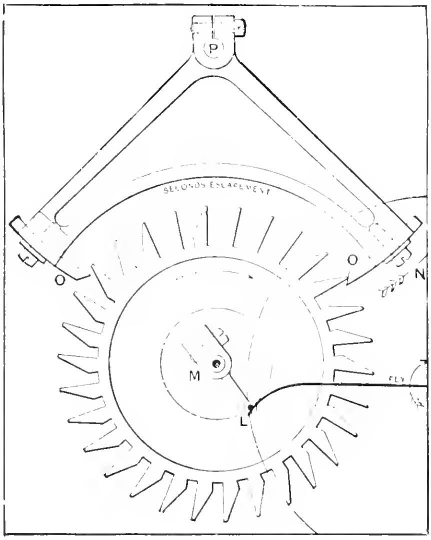


Fig. 29—Dead Beat Escapement

pallets are straight. It is, therefore, inferior to Fig. 27 where the acting surfaces are curved, since these curves give an easier "recoil." This recoil is the slight motion *backwards* which the escape wheel makes at each tick. The "dead beat" escapement is shown in Fig. 29, and is used in clocks of a high grade, generally with a seconds pendulum. It has no recoil as you can easily see that the surfaces O O on which the teeth fall, are portions of a circle around the center P. The beveled ends of these pallets are called the impulse surfaces, and a tooth is just giving the little push on the right-hand pallet. It is found in good railroad clocks, watchmakers' regulators and in many astronomical clocks. These terms are merely comparative, a "regulator" being a good clock and an "astronomical," an extra good one. Figure 30 gives the movement of a "remontoir" clock in which the dead beat shown is used. The upper one of the three dials indicates seconds, and the lever which crosses its center carries the large wheel on the left.

This wheel makes the left end of the lever heavier than the right, and in sinking it drives the clock for one min-

ute, but at the sixtieth second it "remounts" by the action of the clock weight; hence the name, "remontoir." Note here that the big weight does not directly drive the clock; it only rewinds it every minute. The minutes are shown on the dial to the right and its hand jumps forward one minute at each sixtieth second as the lever remounts; so if you wish to set your watch to this clock the proper way is to set it to the even minute "on the jump." The hour hand is on the dial to the left. By this remounting, or rewinding, the clock receives the same amount of driving force each minute. The complete clock is shown in Fig. 31, the large weight which does the rewinding each minute being plainly visible. The pendulum is compensated with steel and aluminum, so that the rate of the clock may not be influenced by hot and cold weather. Was built in 1901 and is the only one I can find room for here. It is fully described in "Machinery," New York, for Nov., 1901. I have built a considerable number, all for experimental purposes, several of them much more complicated than this one, but all differing from clocks for commercial purposes. Pallets like O O in Fig. 29 are often made of jewels; in one clock I used agates and in another, running thirteen months with one winding, I used pallets jeweled with diamonds.

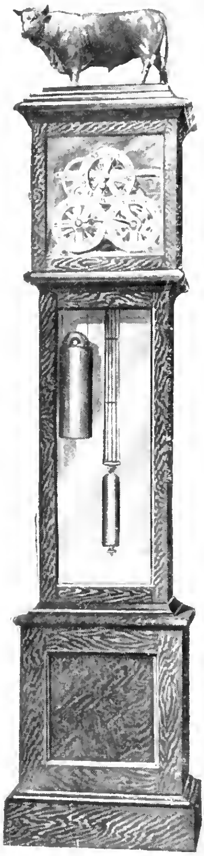


Fig. 31 Remontoir Clock by James Arthur

This is done to avoid friction and wea
Those interested in the improveme
of clocks are constantly striving aft
light action and small driving weight
Conversely, the inferior clock has
heavy weight and ticks loud. Th
"gravity escapement" and others gi
ing a "free" pendulum action would r
quire too much space here, so we mu
be satisfied with the few successfu
ones shown out of hundreds of inve
tions, dozens of them patented. Th
pendulum stands at the top as a tim
measurer and was known to the a
cients for measuring short periods
time just as musicians now use th
metronome to get regular beats. Ga
ileo is credited with noticing its regula
beats, but did not apply it to clock
although his son made a partially su
cessful attempt. The first mathemat
cal investigation of the pendulum wa
made by Huyghens about 1670, and h
is generally credited with applying
to clocks, so there is a "Huyghens
clock with a pendulum instead of th
foliot of De Vick's. Mathematicall
the longer and heavier the pendulu

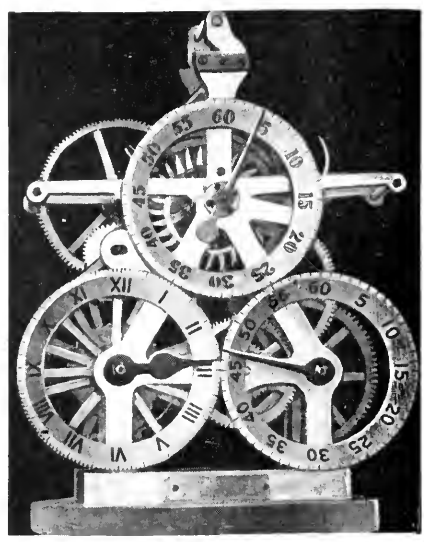


Fig. 30—Remontoir Clock Movement

the better is the time-keeping, b
nature does not permit us to carry an
thing to the extreme; so the difficult

of finding a tower high enough and steady enough, the cumbersomeness of weight, the elasticity of the rod, and many other difficulties render very long and heavy pendulums impracticable beyond about 13 ft. which beats once in two seconds. "Big Ben" of Westminster, London, has one of this length weighing 700 lb. and measuring, over all, 15 ft.

It runs with an error under one second a week. This is surpassed only by some of the astronomical clocks which run sometimes two months within a second. This wonderful timekeeping is done with seconds pendulums of about 39 in., so the theoretical advantage of long pendulums is lost in the difficulties of constructing them. Fractions are left out of these lengths as they would only confuse the explanations. At the Naval observatory in Washington, D. C., the standard clocks have seconds pendulums, the rods of which are nickel steel, called "Invar," which is little influenced by changes of temperature. These clocks are kept in a special basement, so they stand on the solid earth. The clock room is kept at a nearly uniform temperature and each clock is in a glass cylinder exhausted to about half an atmosphere. They are electric remontoirs, so no winding is necessary and they can be kept sealed up tight in their glass cylinders. Nor is any adjustment of their pendulums necessary, or setting of the hands, as the correction of their small variations is effected by slight changes in the air pressure within the glass cylinders. When a clock runs fast they let a little air into its cylinder to raise the resistance to the pendulum and slow it down, and the reverse for slow. Don't forget that we are now considering variations of less than a second a week.

The clock room has double doors, so the outer one can be shut before the inner one is opened, to avoid air currents. Visitors are not permitted to see these clocks because the less the doors are opened the better; but the Commander will sometimes issue a special permit and detail a responsible assistant to show them, so if you wish to see them you must prove to him that you have a head above your shoulders and are worthy of such a great favor.

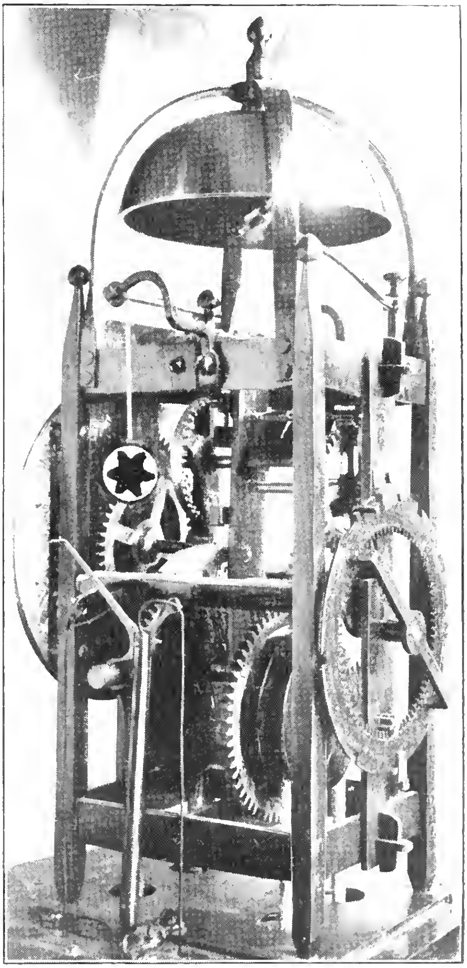


Fig. 32—Antique Clock, Entirely Hand-Made

The best thing the young student could do at this point would be to grasp the remarkable fact that the clock is not an old machine, since it covers only the comparatively short period from 1364 to the present day. Compared with the period of man's history and inventions it is of yesterday. Strictly speaking, as we use the word clock, its age from De Vick to the modern astronomical is only about

540 years. If we take the year 1660, we find that it represents the center of

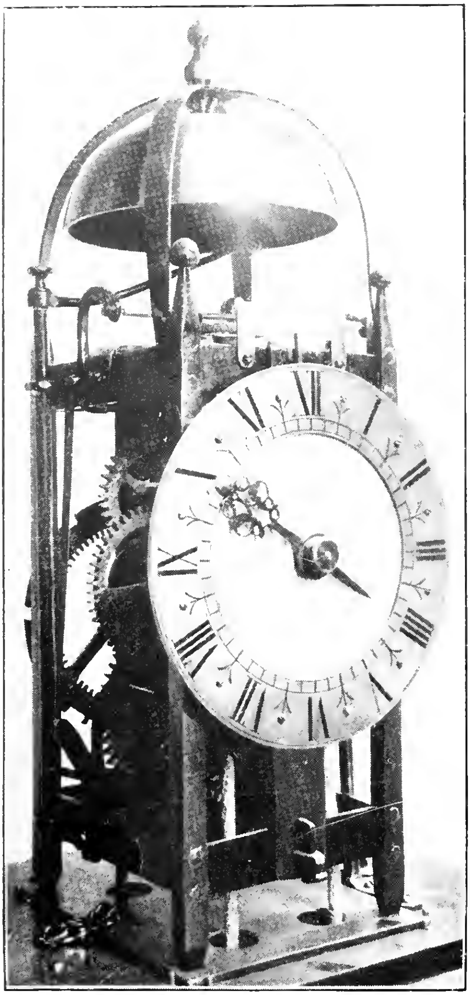


Fig. 33—Antique Clock, Entirely Hand-Made

modern improvements in clocks, a few years before and after that date includes the pendulum, the anchor and dead beat escapements, the minute and second hands, the circular balance and the hair spring, along with minor improvements. Since the end of that period, which we may make 1700, no fundamental invention has been added to clocks and watches. This becomes impressive when we remember that the last 200 years have produced more inventions than all previous known history—but only minor improvements in clocks! The application of electricity for winding, driving, or regulating clocks is not fundamental, for the time-keeping is done by the master clock with its pendulum and wheels, just as by any grandfather's clock 200 years old. This broad survey of time measuring does not permit us to go into minute mechanical details. Those wishing to follow up the subject would require a large "horological library"—and Dr. Eliot's five-foot shelf would be altogether too short to hold the books.

A good idea of the old church clocks may be obtained from Fig. 32 which is one of my valued antiques. Tradition has followed it down as the "English Blacksmith's Clock." It has the very earliest application of the pendulum. The pendulum, which I have marked by a star to enable the reader to find it, is less than 3 in. long and is hung on the verge, or pallet axle, and beats 222 per minute. This clock may be safely put at 250 years old, and contains nothing invented since that date. Wheels are cast brass and all teeth laboriously filed out by hand. Pinions are solid with the axles, or "staffs," and also filed

Fig. 36—Double-Case Watch of Repousse Work

out by hand. It is put together, generally by mortise, tenon and cotter, but

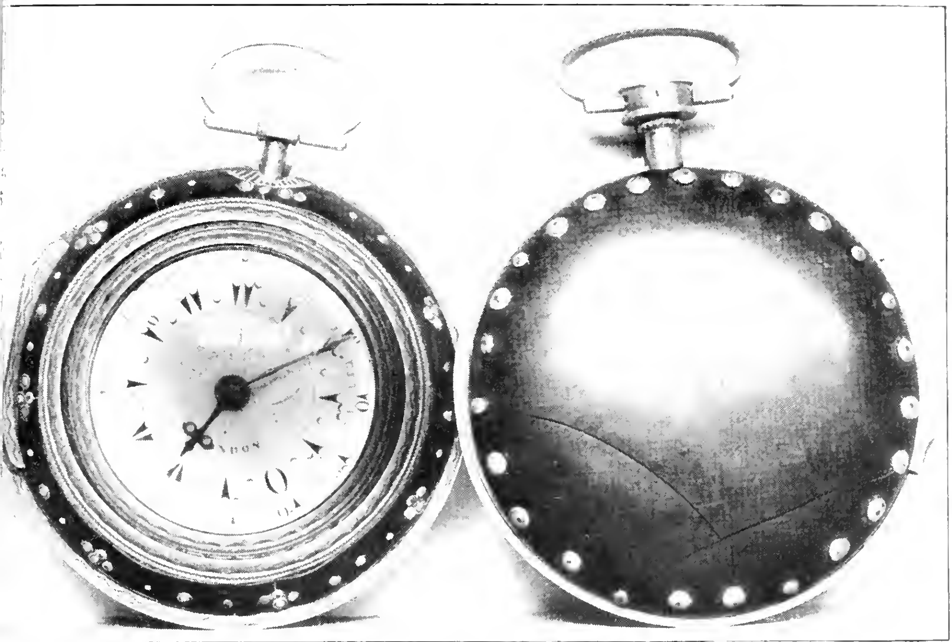


Fig. 34—Triple-Case Turkish Watches

has four original screws all made by
.nd with the file. How did he thread
e holes for these screws? Probably
ade a tap by hand as he made the
rews. But the most remarkable
ature is the fact that no lathe was
ed in forming any part—all staffs,
nions and pivots being filed by hand.
his is simply extraordinary when it is
ointed out that a little dead center
the is the simplest machine in the
orld, and he could have made one in
ss than a day and saved himself
eeks of hard labor. It is probable
at he had great skill in hand work
d that learning to use a lathe would
ve been a great and tedious effort for
m. So we have a complete striking
ock made by a man so poor that he
d only his anvil, hammer and file.
ne weights are hung on cords as thick
an ordinary lead pencil and pass
er pulleys having spikes set around
em to prevent the cords from slip-
ng. The weights descend 7 ft. in 12
urs, so they must be pulled up—not
ound up—twice a day. The single
ur hand is a work of art and is cut
rough like lace. Public clocks may still be seen in Europe with only one hand. Many have been puzzled by finding that old, rudely made clocks often have fine dials, but this is not remarkable when we state that art and engraving had reached a high level before the days of clocks. It is worthy of

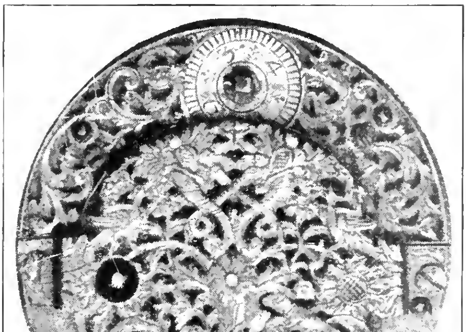


Fig. 38—Watch Showing Dutch Art Work

note that clocks in the early days were generally built in the form of a church

tower with the bell under the dome and Figs. 32, 33 show a good example. It is highly probable that the maker of

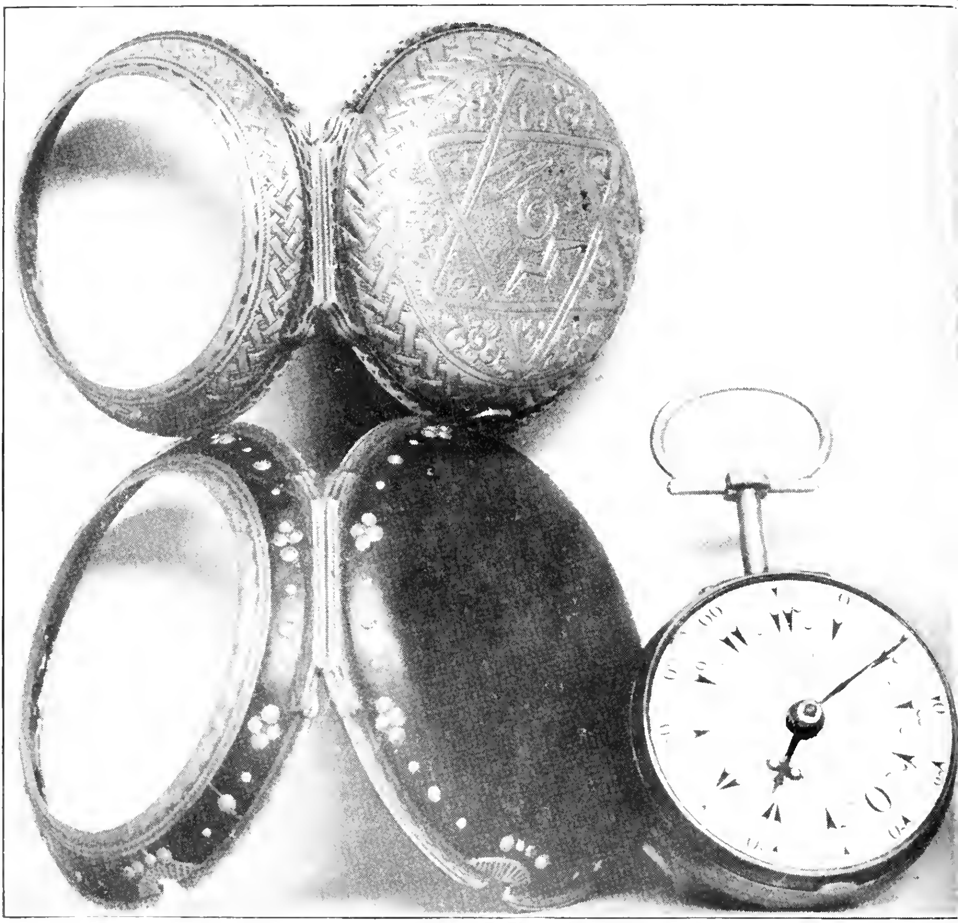


Fig. 35—Triple-Case Turkish Watch

this clock had access to some old church clock—a wonderful machine in those days—and that he laboriously copied it. It strikes the hours, only, by the old "count wheel" or "locking plate" method. Between this and our modern clocks appeared a type showing quarter hours on a small dial under the hour dial. No doubt this was at that time a great advance and looked like cutting time up pretty fine. As the hand on the quarter dial made the circuit in an hour the next step was easy, by simply dividing the circle of quarters into sixty minutes. The old fellows who thought in hours must have

given it up at this point, so the secon and fifths seconds came easily.

The first watches, about 1500, ha

the foliot and verge escapement, and i some early attempts to govern th foliot a hog's bristle was used as spring. By putting a ring around th ends of the foliot and adding the ha spring of Dr. Hooke, about 1640, w have the verge watches of our granc fathers. This balance wheel and ha spring stand today, but the "lever" es capement has taken the place of th verge. It is a modification of the dea beat, Fig. 29, by adding a lever to th anchor, and this lever is acted on b the balance, hence the name "leve watch." All this you can see by oper ing your watch, so no detailed expla

ion is necessary. Figure 34 shows o triple-cased Turkish watches with ge escapements, the one to the left

Cromwell wore an immense triple-case watch of this kind, and the poor plebeians who were permitted to examine

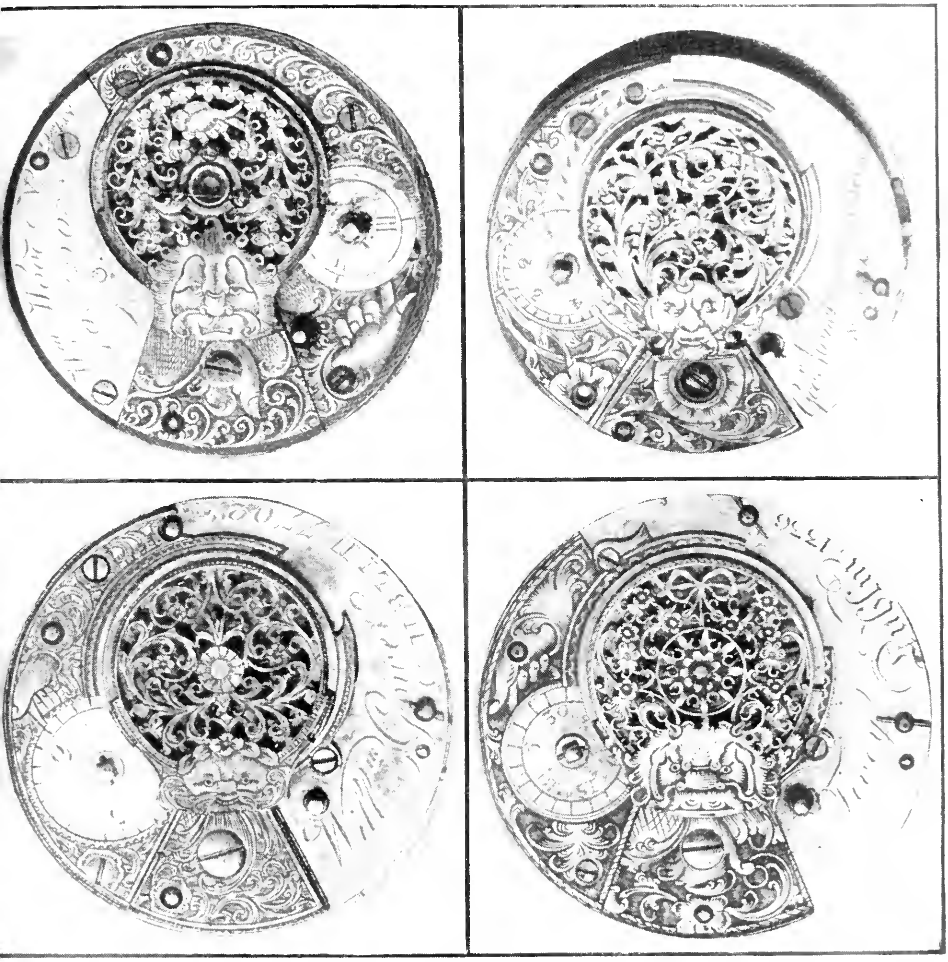


Fig. 37—Watches Showing Art Work

ing shown partly opened in Fig. 35. e watch with its inner case, includ- the glass, is shown to the right. is inner case is complete with two ges and has a winding hole in the ck. The upper case, of "chased" rk, goes on next, and then the third, outer case, covered with tortoise ell fastened with silver rivets, goes outside the other two. When all ree cases are opened and laid on the le, they look like a heap of oyster ells, but they go easily together, ming the grand and dignified watch own to the left in Fig. 34. Oliver

such a magnificent instrument were favored!

Our boys' watches costing one dollar keep much better time than this type of watch. Comparing the Syrian dial, Fig. 42, with that on Fig. 35, it is evident that the strange hour numerals on both are a variation of the same characters. These, so-called, "Turkish watches" were made in Europe for the Eastern trade. First-class samples of this triple-case type are getting scarce, but I have found four, two of them in Constantinople. Figure 36 shows the double-case style, called

"pair cases," the outer case thin silver, the figures and ornaments being hammered and punched up from the inside

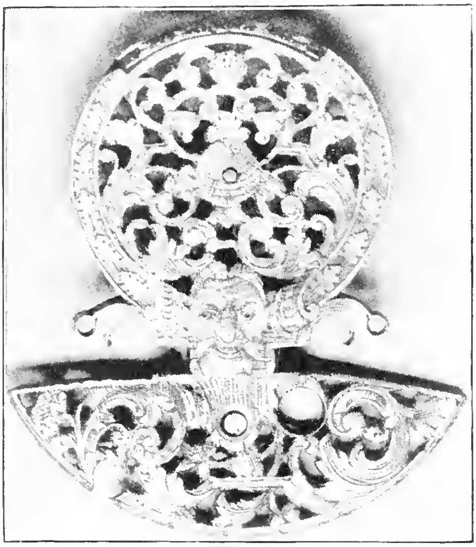


Fig. 39—Antique Watch Cock

and called "repoussé." Before we leave the old watches, the question of art work deserves notice, for it looks as if ornamentation and time-keeping varied inversely in those days—the more art the worse the watch. I presume, as they could not make a good time-keeper at that date, the watchmaker decided to give the buyer something of great size and style for his money. In Fig. 37 four old movements are shown, and there is no doubt about the art, since the work is purely individual and no dies or templates used. In examining a large number of these watches, I have never found the art work on any two of them alike. Note the grotesque faces in these, and in Fig. 39 which is a fine example of pierced, engraved work. Figure 38 is a fine example of pierced work with animals and flowers carved in relief. Figure 40 is a "Chinese" watch but made in Europe for the Chinese market. In Fig. 41 we have what remains of a quarter repeater with musical attachment. Each of the 24 straight gongs, commencing with the longest one, goes a little nearer the center of the large wheel, so a circle of pins set in the wheel for each gong, or not and there is plenty of room for sever tunes which the wearer can set off pleasure. Figure 43 is a modern wat with Hebrew hour numerals. Figu 44 is a modern 24-hour watch used o some railroads and steamship lines. have a pretty clean-cut recollection one event in connection with the 2 hour system, as I left Messina betwee 18 and 19 o'clock on the night of th earthquake! Dials and hands const tute an important branch of the su ject. The general fault of hands is th they are too much alike; in many i stances they are the same, exceptin that the minute hand is a little long than the hour. The dial shown on th left of Fig. 24 was designed by me fo a public clock and can be read twice a far away as the usual dial. Just wh we should make the worst dials an hands for public clocks in the Unit States is more than I can find out, fo there is no possible excuse, since th "spade and pointer" hands have bee known for generations. Figure 45 offered as a properly designed dial fo watches and domestic clocks, havin flat-faced Gothic figures of modera height, leaving a clear center in th dial, and the heavy "spade" hour han

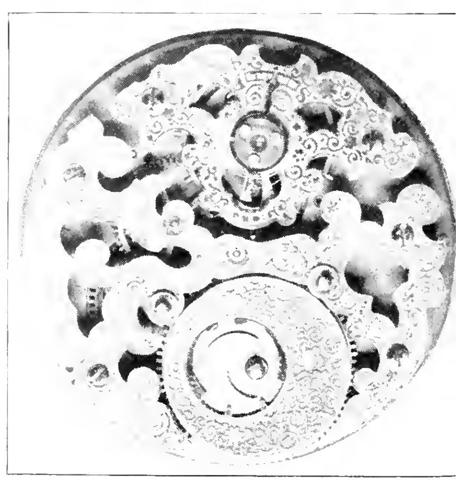


Fig. 40—"Chinese" Watch

reaching only to the inner edges of th figures. For public clocks the Arab

umerals are the worst, for at a distance they look like twelve thumb marks on the dial; while the flat-faced Roman remain distinct as twelve clear marks.

Do you know that you do not read a public clock by the figures, but by the position of the hands? This was discovered long ago. Lord Grimthorp had one with twelve solid marks on the dial and also speaks of one at the Athenæum Club, both before 1869. The Philadelphia City Hall clock has dials of this kind as shown on right side of Fig. 21. It has also good hands and can be read at a great distance. Very few persons, even in Philadelphia, know that it has no hour numerals on its dials. Still further, there is no clock in the tower, the great hands being moved every minute by air pressure which is regulated by a master clock set in a clock room down below where the walls are 10 ft. thick. Call and see this clock and you will find that the City Hall officials sustain the good name of Philadelphia for politeness. Generally, we give no attention to the hour numerals, even of our watches, as the following proves. When you have taken out your watch and looked at the time, for yourself, and put it back in your pocket, and when a friend asks

Fig. 41—Musical Watch, Repeating Hours and Quarters

the time you take it out again to find the time for him! Why? Because, for yourself, you did not read hours and minutes, but only got a mental impres-

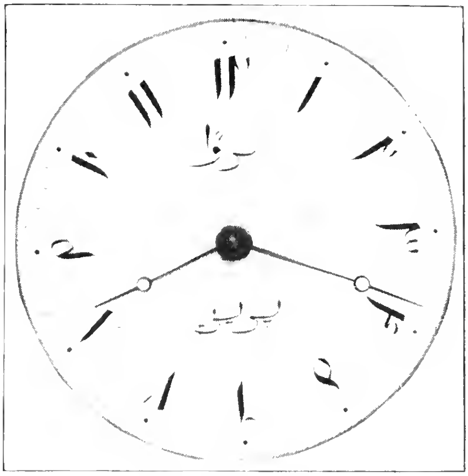


Fig. 42—Syrian Dial

sion from the position of the hands; so we only read hours and minutes when we are called on to proclaim the time.

We must find a little space for striking clocks. The simplest is one blow at each hour just to draw attention to the clock. Striking the hours and also one blow at each half hour as well as the quarter double blow, called "ting tong" quarters, are too well known to need description. The next stage after this is "chiming quarters" with three or more musical gongs, or bells. One of the best strikers I have has three trains, three weights and four bells. It strikes the hour on a large bell and two minutes after the hour it strikes it again, so as to give you another chance to count correctly. At the first quarter it repeats the last hour followed by a musical chord of three bells, which we will call *one triple blow*: at the second quarter the hour again and two triple blows and at the third quarter, the hour again and three triple blows. Suppose a sample hour's striking from four o'clock, this is what you hear, and there can be no mistake. "Four" and in two minutes "four"—"four and one quarter"—"four and two quarters"—"four and three quarters," and the same for all other hours. This is definite, for the clock proclaims the

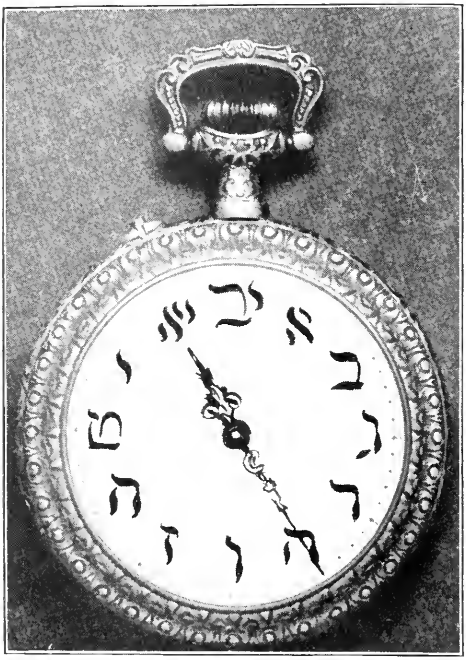


Fig. 43—Hebrew Numerals

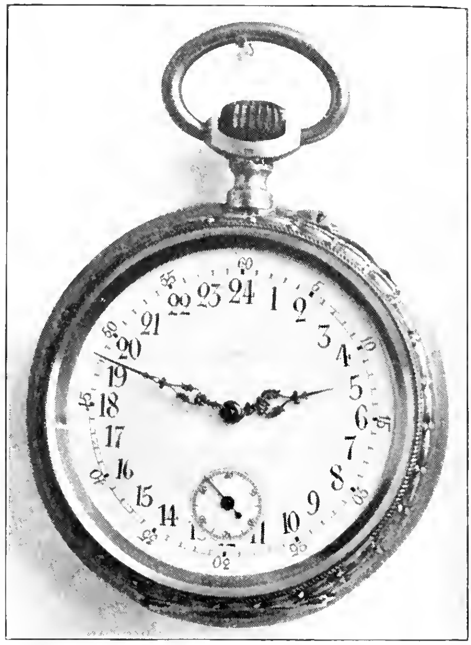


Fig. 44—24-Hour Watch

hour, or the hour and so much past. It can be set silent, but that only stops it from striking automatically, and whether so set or not, it will repeat by pulling a cord. You awake in the night and pull the cord, and then in mellow musical tones, almost as if the clock were speaking, you hear—"four and two quarters." This I consider a perfect striking clock. It is a large movement of fine workmanship and was made in the department of the Jura, France. When a clock or watch only repeats, I consider the old "five-minute repeater" the best. I used this method in a clock which, on pulling the cord, strikes the hour on a large bell and if that is all it strikes, then it is less than five minutes past. If more than five minutes past it follows the hour by one blow on a small bell for every five minutes. This gives the time within five minutes. It is fully described and illustrated in "Machinery," New York, for March, 1905. Just one more. An old Dutch clock which I restored strikes the hour on a large bell; at the first quarter it strikes one blow on a small bell; at the half hour it strikes the last hour over again on the small bell; at the third quarter it strikes one blow on the large bell. But this in spite of its great ingenuity, only gives definite information at the hour and half hour.

Of curious clocks there is no end, so I shall just refer to one invented by William Congreve, an Englishman, over one hundred years ago, and often coming up since as something new. A plate about 8 in. long and 4 in. wide has a long zigzag groove crosswise. This plate is pivoted at its center so either end can be tipped up a little. A ball smaller than a boy's marble will roll back and forth across this plate till it reaches the lower end, at which point it strikes a click and the main-spring of the clock tips the plate the other way and the ball comes slowly back again till it strikes the disk at the other end of the plate, etc. Every time the plate tips, the hands are moved a little just like the remontoir clock already described. Clocks of this kind are often used for deceptive purposes

nd those ignorant of mechanics are eceived into the belief that they see erpetual motion. The extent to which iodern machine builders are indebted ɔ the inventions of the ancient clock-iaker, I think, has never been appreci-ted.

In its earlier stages the clock was al-iost the only machine containing ɔothed gearing, and the "clock tooth" ; still necessary in our delicate ma-hines. It is entirely different from our tandard gear tooth as used in heavy iachines. The clock-makers led for a ɔng time in working steel for tools, prings and wearing surfaces. They lso made investigations in friction, earings, oils, etc., etc. Any one re-toring old clocks for amusement and leasure will be astonished at the high-lass mechanics displayed in them—early always by unknown inventors. lere is an example: The old clock-iaker found that when he wished to rill a hole in a piece of thick wire so s to make a short tube of it, he could nly get the hole central and straight y rotating the piece and holding the rill stationary. By this method the rill tends to follow the center line of rotation; and our great guns as well as our small rifles are bored just that way to get bores which will shoot straight.

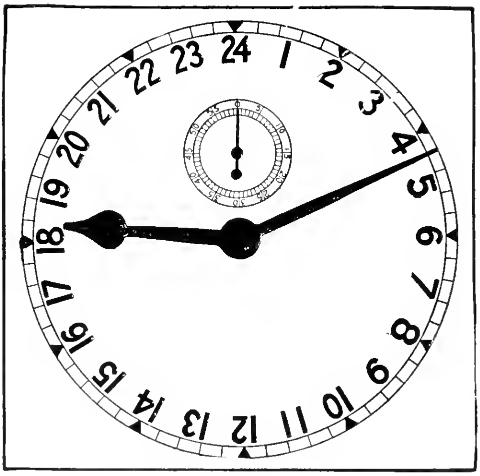


Fig. 45—Domestic Dial by James Arthur

The fourth and last chapter will deal with the astronomical motions on which our time-keeping is founded, our present hour zones of time, and close with suggestions for a universal time system over the whole world.

CHAPTER IV

ASTRONOMICAL FOUNDATION OF TIME

Astronomical motions on which our time is founded.—Reasons for selecting the sidereal day as a basis for our 24-hour day.—Year of the seasons shorter than the zodiacal year.—Precession of the equinoxes.—Earth's rotation most uniform motion known to us.—Time Stars and Transits.—Local time.—The date line.—Standard time.—Beginning and ending of a day—Proposed universal time.—Clock dial for universal time and its application to business.—Next great improvement in clocks and watches indicated.—Automatic recording of the earth's rotation.—Year of the seasons as a unit for astronomers.—General conclusions.

CHAPTER IV

The mystery of time encloses all ıings in its folds, and our grasp of its .finite bearings is measured by our mitations. As there are no isolated cts in the Universe, we can never get the end of our subject; so we know ıly what we have capacity to absorb. ı considering the foundation on which l our time measuring is based, we re led into the fringe of that Elysian eld of science—astronomy. A science more poetical than poetry—more ıarming than the optimistic phantaes of youth. That science which aves our imagination helpless; for its cts are more wonderful than our exemest mental flights. The science of ıstness and interminable distances hich our puny figures fail to express. The stars sang together for joy," ight almost be placed in the category facts; while the music of the spheres ay now be considered a mathematical ality. Our time keeping is inevitably ssociated with these motions, and we ıust select one which has periods not o long. That is, no *continuous* moon could be used, unless it passed me species of milestones which we ould observe. Consequently, our ocks do not—in the strict sense—easure time; but are adjusted to *vide* periods which they do not deterine. We are constantly correcting ıeir errors and never entirely suceed in getting them to run accutely to *periods of time* which exist ıtirely outside of such little things men and clocks. So a clock is etter as it approximates or bears a gular *relation* to some motion in ature. The sidereal clock of the asonomer *does* run to a regular motion; ıt our 24-hour clocks *do not*, as we ıall see later. Now consider the year, the sun's apparent motion in the odiac, from any given star around to ıe same one again. This is altogether o long to be divided by clocks, as we annot make a clock which could be depended on for anywhere near a year. The next shorter period is that of a "moon." This is also a little too long, is not easily observed, and requires all sorts of corrections. Observations of the moon at sea are so difficult and subject to error that mariners use them only as a last resort. If a little freedom of language is permissible, I would say that the moon has a bad character all around, largely on account of her long association with superstition, false theology and heathen feasts. She has not purged herself even to this day! The ancients were probably right when they called erratic and ill-balanced persons "luny." Now we come to the day and find that it is about the right practical length—but what kind of a day? As there are five kinds we ought to be able to select one good enough. They are:—

1st. The solar day, or noon to noon by the sun.

2nd. An imaginary sun moving uniformly in the ecliptic.

3rd. A second imaginary sun moving uniformly parallel to the equator at all seasons of the year.

4th. One absolute rotation of the earth.

5th. One rotation of the earth measured from the node, or point, of the spring equinox.

The difference between 1st and 2nd is that part of the sun's error due to the elliptical orbit of the earth.

The other part of the sun's error—and the larger—between 2nd and 3rd is that due to the obliquity of the ecliptic to the equator.

The whole error between 1st and 3rd is the "equation of time" as shown for even minutes in the first chapter under the heading, "Sun on Noon Mark 1909."

Stated simply, for our present purpose, 1st is sundial time, and 3rd our 24-hour clock time.

This 2nd day is therefore a refinement of the astronomers to separate

the two principal causes of the sun's error, and I think we ought to handle it cautiously, or my friend, Professor Todd, might rap us over the knuckles for being presumptuous.

This 5th day is the sidereal day of the astronomers and is the basis of our time, so it is entitled to a little attention. I shall confine "sidereal day" to this 5th to avoid confusion with 4th. If you will extend the plane of the equator into the star sphere, you have the celestial equator. When the center of the sun passes through this plane on his journey north, in the Spring, we say, "the sun has crossed the line." This is a distant point in the Zodiac which can be determined for any given year by reference to the fixed stars. To avoid technicalities as much as possible we will call it the point of the Spring equinox. This is really the point which determines the common year, or year of the seasons. Using popular language, the seasons are marked by four points,—Spring equinox—longest day; Autumnal equinox—shortest day. This would be very simple if the equinoctial points would stay in the same places in the star sphere; but we find that they creep westward each year to the extent of 50 seconds of arc in the great celestial circle of the Zodiac. This is called the precession of the equinoxes. The year is measured from Spring equinox to Spring equinox again; but each year it comes 50 seconds of arc less than a full revolution of the earth around the sun. Therefore *if we measured our year by a full revolution* we would displace the months with reference to the seasons till the hot weather would come in January and the cold weather in July in about 13,000 years; or a complete revolution of the seasons back to where we are, in 26,000 years. Leaving out fractions to make the illustration plain, we have:—

$$\left.\begin{array}{ll}
(1) & \dfrac{\text{360 degrees of Zodiac}}{\text{50 seconds of arc}} = \text{26,000 years} \\[2ex]
(2) & \dfrac{\text{1 day of time}}{3\tfrac{1}{3}\text{ seconds}} = \text{26,000 years} \\[2ex]
(3) & \dfrac{\text{1 year of time}}{20\tfrac{1}{3}\text{ minutes}} = \text{26,000 years} \\[2ex]
(4) & \dfrac{3\tfrac{1}{3}\text{ seconds}}{\text{days in a year}} = \dfrac{1}{110}\text{ of a second}
\end{array}\right\}\ \text{All Approximate}$$

In (1) we see that a "precession" of 50 seconds of arc will bring the Sprin[g] equinox around in 26,000 years.

In (2) we see, as 50 seconds of a[rc] represents the distance the earth w[ill] rotate in 3 1/3 seconds, a difference [of] one day will result in 26,000 year[s]. That is since the clock regulated by th[e] stars, or absolute rotations of the eart[h] would get behind 3 1/3 seconds p[er] year, it would be behind a day [in] 26,000 years, as compared with a s[i]dereal clock regulated by the Sprin[g] equinoctial point.

In (3) we see that as 50 seconds [of] arc is traversed by the earth, in i[ts] annual revolution, in 20 1/3 minute[s] a complete circle of the Zodiac will [be] made in 26,000 years.

In (4) we see that as the differen[ce] between the year of the seasons and t[he] Zodiacal year is 3 1/3 seconds of t[he] earth's rotation, it follows that if th[is] is divided by the number of days in [a] year we have the amount which [the] sidereal day is less than 4th, or an abs[o]lute rotation of the earth. That is, a[ny] meridian passes the Spring equinocti[al] point 1/110 of a second sooner than t[he] time of one absolute rotation. The[se] four equations are all founded on t[he] precession of the equinoxes, and a[re] simply different methods of stating [it.] Absolutely and finally, our time is reg[u]lated by the earth's rotation; b[ut] strange as it may appear, we do n[ot] take one rotation as a unit. As show[n] above, we take a rotation to a *movab[le] point* which creeps the 1/110 of a seco[nd] daily. But after all, it is the *unifor[m]* rotation which governs. This is t[he] one "dependable" motion which has n[ot] been found variable, and is the mo[st] easily observed. When we rememb[er] that the earth is not far from being [as] heavy as a ball of iron, and that [its] surface velocity at the equator is abo[ut] 17 miles per minute, it is easy to form [a] conception of its uniform motio[n.] Against this, however, we may pla[ce] the friction of the tides, forcing up [of] mountain ranges, as well as mining a[nd] building skyscrapers—all tending [to] slow it. Mathematicians moving in t[he] ethereal regions of astronomy lead

o conclude that it *must* become graduilly slower, and that *it is* slowing; but he amount may be considered a vanshing quantity even compared with the smallest errors of our finest clocks; so or uncounted generations past—and to come—we may consider the earth's rotation uniform. Having now found ı uniform motion easily observed and of convenient period, why not adopt it is our time unit? The answer has been partially given above in the fact hat we are compelled to use a year, neasured from the Spring equinoctial point, so as to keep our seasons in order; and therefore as we must have some point where the sidereal clocks ınd the meantime clocks coincide, we ake the same point, and that point is he Spring equinox. Now we have hree days:—

1st. A sidereal day 1/110 of a second less than one rotation of the earth.

2nd. One rotation of the earth in 23 ıours, 56 minutes and 4 seconds, nearly, of clock time.

3rd. One mean time clock day of 24 ıours, which has been explained preiously.

Now, isn't it remarkable that our 24-ıour day is purely artificial, and that ıothing in nature corresponds to it? Our real day of 24 hours is a *theoretical* lay. Still more remarkable, this theoetical day is the unit by which we express motions in the solar system. A unar month is days—hours—minutes —and seconds of this theoretical day, nd so for planetary motions. And still nore remarkable, the earth's rotation vhich is *itself* the foundation is expressed in this imaginary time! This ooks like involution involved, yet our 4-hour day is as real as reality; and the nan has not yet spoken who can tell vhether a mathematical conception, ustained in practical life, is less real han a physical fact. Our legal day of practical life is therefore deduced from he day of a fraction *less* than one earth otation. In practice, however, the mall difference between this and a otation is often ignored, because as he tenth of a second is about as near s observations can be made it is evident that for single observations 1/110 of a second does not count, but for a whole year it does, and amounts to 3 1/3 seconds. Now as to the setting of our clocks. While the time measured by the point of the Spring equinox is what we must find it is found by noting the transits of fixed stars, because *the relation* of star time to equinoctial time is known and tabulated. Remember we cannot take a transit of the equinoctial point, because there is nothing to see, and that *nothing* is moving! But it can be observed yearly and astronomers can tell where it is, at any time of the year, by calculation. The stars which are preferred for observation are called "time stars" and are selected as near the celestial equator as possible. The earth's axis has a little wabbling motion called "nutation" which influences the *apparent* motion of the stars near the pole; but this motion almost disappears as they come near the equator, because nutation gives the plane of the equator only a little "swashplate" motion. The positions of a number of "time stars" with reference to the equinoctial point, are known, and these are observed and the observations averaged. The distance of any time star from the equinoctial point, *in time*, is called its "right ascension." Astronomers claim an accuracy to the twentieth part of a second when such transits are carefully taken, but over a long period, greater exactness is obtained. Really, the time at which any given star passes the meridian is taken, *in practical life*, from astronomical tables in the Nautical Almanacs. Those tables are the result of the labors of generations of mathematicians, are constantly subject to correction, and cannot be made simple. Remember, the Earth's rotation is the only uniform motion, all the others being subject to variations and even compound variations. This very subject is the best example of the broad fact that science is a constant series of approximations; therefore, nothing is exact, and nothing is permanent but change. But you say that mathematics is an exact science. Yes, but it is a *logical abstraction*, and is therefore only

the universal solvent in physical science.

With our imaginary—but real—time unit of 24 hours we are now ready to consider "local time." Keeping the above explanation in mind, we may use the usual language and speak of the earth rotating in 24 hours clock time; and since motion is relative, it is permissible to speak of the motion of the sun. In the matter of the sun's apparent motion we are compelled to speak of his "rising," "setting," etc., because language to express the motion in terms of the earth's rotation has not been invented yet. For these reasons we will assume that in Fig. 47 the sun is moving as per large arrow and also that the annulus, half black and half white, giving the 24 hours, is fastened to the sun by a rigid bar, as shown, and moves around the earth along with him. In such illustrations the sun must always be made small in proportion, but this rather tends to plainness. For simplicity, we assume that the illustration represents an equinox when the sun is on the celestial equator. Imagine your eye in the center of the sun's face at A, and you would be looking on the meridian of Greenwich at 12 noon; then in one hour you would be looking on 15° west at 12 noon; but this would bring 13 o'clock to Greenwich. Continue till you look down on New York at 12 noon, then it is 17 o'clock at Greenwich (leaving out fractions for simplicity) etc. If you will make a simple drawing like Fig. 47 and cut the earth separate, just around the inside of the annulus, and stick a pin at the North Pole for a center, you may rotate the earth as per small arrow and get the actual motion, but the result will be just the same as if you went by the big arrow. We thus see that every instant of the 24 hours is represented, at some point, on the earth. That is, the earth has an infinity of local times; so it has every conceivable instant of the 24 hours at some place on the circle. Suppose we set up 1,440 clocks at uniform distances on the equator, then they would be about 17 miles apart and differ by minutes. Now make it 86,400 clocks, they would be 1,500 feet apart and differ by seconds. With 864,000 clocks they would be 150 feet apart and vary by tenths of seconds. It is useless to extend this, since you could always imagine more clocks in the circle; thus establishing the fact that there are an infinity of times at an infinity of places always on the earth. It is necessary to ask a little patience here as I shall use this local time and its failure later in our talk. Strictly, local time has never been used, because it has been found impracticable in the affairs of life. This will be plain when we draw attention to the uniform time of London which is Greenwich time; yet the British Museum is 30 seconds slow of Greenwich, and other places in London even more. This is railroad time for Great Britain; but it is 20 minutes too fast for the west of England. This led to no end of confusion and clocks were often seen with two minute hands, one to local and the other to railroad time. This mixed up method was followed by "standard time," with which we are all pretty well acquainted. Simply, standard time consists in a uniform time for each 15° of longitude, but this is theoretical to the extreme, and is not even approached in practice. The first zone commences at Greenwich and as that is near the eastern edge of the British Islands, their single zone time is fast at nearly all places, especially the west coast of Ireland. When we follow these zones over to the United States we find an attempt to make the middle of each zone correct to local time, so at the hour jumping points, we pass from half an hour slow to half an hour fast, or the reverse. We thus see that towns about the middle of these four United States zones have sunrise and sunset and their local day correct, but those at the eastern and western edges average half an hour wrong. As a consequence of this disturbance of the working hours depending on the light of the day, many places keep two sets of clocks and great confusion results. Even this is comprehensible; but it is a mere fraction of the trouble and con-

plication, because the hour zones are not separated by meridians in practice, but by zig-zag lines of great irregularity. Look at a time map of the United States and you will see the zones divided by lines of the wildest irregularity. Now question one of the brightest "scientific chaps" you can find in one of the great railroad offices whose lines touch, or enter, Canada and Mexico. Please do not tell me what he said to you! So great is the confusion that no man understands it all. The amount of wealth destroyed in printing time tables, *and failing to explain them*, is immense. The amount of human life destroyed by premature death, as a result of wear and tear of brain cells is too sad to contemplate. And all by attempting the impossible; for local time, *even if it was reduced to hourly periods* is not compatible with any continental system of time and matters can only get worse while the attempt continues. For the present, banish this zone system from your mind and let us consider the beginning and ending of a day, using strictly local time.

A civil, or legal, day ends at the instant of 24 o'clock, midnight, and the next day commences. The time is continuous, the last instant of a day touching the first instant of the next. This is true for all parts of the earth; but something *in addition* to this happens at a certain meridian called the 'date line." Refer again to Fig. 47 which is drawn with 24 meridians representing hours. As we are taking Greenwich for our time, the meridians are numbered from 0°, on which the observatory of Greenwich stands. When you visit Greenwich you can have the pleasure of putting your foot on "the first meridian," as it is cut plainly across the pavement. Degrees of longitude are numbered east and west, meeting just opposite at 180°, which is the "date line." Our day begins at this line, so far as *dates* are concerned; but the *local day* begins everywhere at midnight. Let us start to go around the world from the date line, westward. When we arrive at 90° we are one quarter

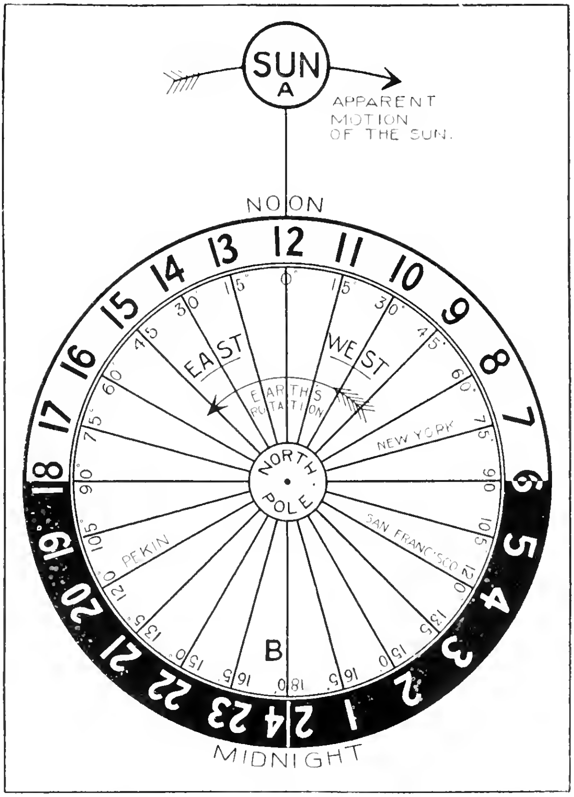


Fig. 47—Local Time—Standard Time—Beginning and Ending of the Day

around and it takes the sun 6 hours longer to reach us. At 0° (Greenwich) we are half around and 12 hours ahead of the sun motion. At 90° west, three quarters, or 18 hours, and when back to 180° we have *added* to the length of all days of our journey enough to make one day; therefore our date must be one day behind. Try this example to change the wording:—Let us start from an island B, just west of the date line. These islanders have their 24-hour days, commencing at midnight, like all other places. As we move westward our day commences later and

later than theirs, as shown above. Suppose we arrive at the eastern edge of the 180° line on Saturday at 12 o'clock, but before we cross it we call over to the islanders,—what day is it? We would get answer, "Sunday;" because all our days have been longer, totalling one day in the circuit of the globe. So if we step over the line at 12 o clock Saturday, presto, it is 12 o'clock Sunday. It looks like throwing out 24 hours, but this is not so, since we have lived exactly the same number of hours and seconds as the islanders. In this supposition we have all the *dates*, however, but have jumped half of Saturday and half of Sunday, which equals one day. In practice this would not have been the method, for if the ship was to call at the island, the captain would have changed date on Friday night and thrown Saturday out, all in one piece, and would have arrived on their Sunday; so his log for that week would have contained only 6 days. It is not necessary to go over the same ground for a circuit of the globe eastward, but if you do so you will find that you *shorten* your days and on arriving at the date line would have a day too much; so in this case you would *double* a date and have 8 days in that week. In both cases this is caused by compounding your motion with that of the sun; going with him westward and lengthening your days, or eastward meeting him and shortening them. Figure 47 shows Greenwich noon, we will say on Monday, and at that instant, Monday only, exists from 0 to 24 o'clock on the earth; but the next instant, Tuesday begins at 180° B. In one hour it is noon of Monday at 15° West, and midnight at 165° East; so Tuesday is one hour old and there is left 23 hours of Monday. Monday steadily declines to 0 as Tuesday steadily grows to 24 hours; so that, except at the instant of Greenwich noon, there are always two days on the world at once. If we said that there are *always* two days on the world at once, we could not be contradicted; since there is no conceivable time between Monday and Tuesday; it is an instantaneous change. As we cannot conceive of *no time*, the statement that there is only one day on the earth at Greenwich noon is not strictly permissible. Since there are always two days on the world at once let us suppose that these two are December 31st and January 1st; then we have *two years* on the world at once for a period of 24 hours. Nine years ago we had the 19th and 20th centuries on the world at once, etc. As a mental exercise, you may carry this as far as you please. Suppose there was an impassable sea wall built on the 180° meridian, then there would be two days on the world, just as explained above but, *practically*, there would be no date line, since in sailing west to this wall we would "lengthen our days," and then shorten them the same amount coming around east to the other side of the wall, but would never jump or double a date. This explanation is founded, as it ought to be, on uniform local time, and is the simplest I can give. The date line is fundamentally simple, but is difficult to explain. When it is complicated by the standard time —or jumping hour system—and also with the fact that some islands count their dates from the wrong side of the line for their longitudes, scientific paradoxes arise, such as having three dates on the world at once, etc.; but as these things are of no more value than wasting time solving Chinese puzzles, they are left out. Ships change date on the nearest night to the date line; but if they are to call at some island port in the Pacific, they may change either sooner or later to correspond with its date. Here is a little Irish date line wit printed for the first time,—I was telling my bright friend about turning in on Saturday night and getting up for breakfast on Monday morning. "Oh," said he, "I have known gentlemen to do as good as that without leaving New York City!"

As what is to follow relates to the growing difficulties of local time and a proposed method of overcoming them let us recapitulate:—

1st. Local time has never been kept

and the difficulties of using it have increased as man advanced, reaching a climax of absurdity on the advent of the railroad; so it broke down and became impractical.

2nd. To make the irregular disorder of local time an orderly confusion, the "standard time"—jumping by hours—has helped a little, but only because we can tell how much it is wrong at any given place. This is its only advantage over the first method, where we had no means of knowing what to expect on entering any new territory. That is, we have improved things by throwing out local time to the extent of an hour.

My proposal is to throw local time out *totally* and establish one, invariable, *universal time.* Greenwich time being most in use now, and meridians numbered from it, may be taken in preference to any other. Still another reason is that the most important timekeepers in modern life—ship's chronometers—are set to Greenwich time. Universal time—no local time—only local day and night. Our 24-hour system is all right, so do not disturb it, as it gets rid of A.M. and P.M. and makes the day our unit of time. Our railroad time now throws out local time to the extent of one hour; but I propose to throw it out entirely and never change the clock hands from Greenwich time. The chronometers do that now, so let us conduct all business to that time.

Now refer to Fig. 46, in which Greenwich is taken as universal time. The annulus, half white and half black, indicates the average day and night, and is a separate ring in the dial which can be set so that "noon" is on the meridian of the place, as shown for four places in the illustration. It is the same dial in all four cases set to local day and night. Strictly, the local time conception is dropped and the local day left for regulating working and sleeping time. All business would have the same time. In traveling east we would not have the short hours; or west, the long hours. All clocks and watches would show the same time as ship's chronometers do now. The only change would be the names of the hours for the parts of the local day. This is just the difficulty, for we are so accustomed to *associate* a certain number, as seven, with the morning and breakfast time. Suppose breakfast time in London is 7 o'clock, then according to the local day it would be 12 o'clock breakfast time in New York; but in both cases it would be the same time with reference to the *local daylight.* Let it be distinctly understood that our association of *12 o'clock* with *noon* is not necessary. The Japanese called it "horse" and "nine"—the ancient Romans, the New Testament writers, and the Turks called it the "sixth hour"—the astronomers now call it 24 o'clock, and the Chinese represent it by several characters; but, in all cases, it is simply the middle of the day at any place. By the proposed universal time, morning, noon, and evening would be—*at any given place*—the same hours. There would be no necessity of establishing legal noon with exactness to the meridian, because that would only regulate labor, meals, etc., and would not touch universal time. This is an important part of the proposal and is worth elaborating a little. Sections in manufacturing districts could make their working hours correspond at pleasure and no confusion would result. That is, local working hours to convenience but by the same universal time. Note how perfectly this would work in traveling,—you arrive in Chicago from the effete east and your watch corresponds all along with the railroad clocks. As you leave the station you glance up at the clock and see that Chicago noon is 17.30, so you set the day and night ring of your watch to match the same ring on the clock, but no disturbance of the hands. As you register at the hotel you ask,—dinner? and get answer, 24.30—then breakfast, 12.30. These questions are necessary now, so I do not add complication here. When you arrive in a strange city you must ask about meals, business hours, theater hours, "doors open" hours, etc., etc.; so all this remains the same. Let us put the matter forcibly,—while we count days, or *dates, something* must

vary with east and west; I propose the fixing of hours for business and sleep to suit each locality, but an invariable time. Get rid of the idea that a certain number, as 7 o'clock, represents the age of the day *at all places.* See how this would wipe out the silly proposal to "save daylight" by setting the clock back and forward. Suppose workmen commenced at 12.30 in New York; for the long summer days make it 11.30, but no change in universal time. As this is the only difference from our present time system, keep the central conception, firmly,—universal time—local day and night.

Suppose Chicago decided that "early to bed and early to rise" was desirable; then it could establish its legal noon as 17.30, which would be about 20 minutes early for its meridian. You could do business with Chicago for a lifetime and not find this out, unless you looked up the meridian of Chicago and found that it was 17.50 o'clock. None of the railroads or steamship lines of the city would need to know this, except as a matter of scientific curiosity, for the time tables would all be printed in universal time. For hiring labor, receiving and delivering goods, etc., they would only need to know Chicago *business hours.* To state the matter in different words,—Chicago would only need to decide what portion of the universal 24 hours would suit it best for its day and which for its night, and if it decided, as supposed above, to place its working day forward a little to give some daylight after labor, nothing would be disturbed and only the scientific would ever know. Certainly, "save daylight," but do not make a fool of the clock! Having shown the great liberty which localities could take without touching the working of the system, the same remarks apply to ultra-scientific localities. A city might establish its noon to the instant; so it is possible—even if a little improbable—that the brilliant and scientific aldermen of New York might appoint a commission with proper campfollowers and instrument bearers to determine the longitude of the city to the Nth of a second and tell us where we "are at." The glory of this achievement—and especially its total cost—would be all our own and incorruptible time would be untouched! We thus see that great local freedom and great accuracy are alike possible. With our present system, accuracy in local time is impracticable and has never even been attempted, and is confusion confused since we added the railroad hour jumps. Why did we nurse this confusion till it has become almost intolerable? Because man has always been a slave to *mental associations, and habits.* Primitive man divided the local day into parts and gave them names and this mental attitude sticks to us after it has served its day. The advantages of universal time could hardly be enumerated, yet we can have them all by dropping our childish association of 7 o'clock with breakfast time! Another example,—you visit a friend for a few days and on retiring the first night you ask "what is your breakfast hour"—"8 o'clock." You have to ask this question and recollect the answer. Now tell me what difference it would make if the answer had been 13 o'clock? None whatever, unless, perhaps, that is, you do not like thirteen! You ask, how about ships? Ships now carry universal time and only change the clock on deck to please the simple minded passengers. How about the date line? No change whatever, so long as we use *dates* which means numbering local days. It is useless multiplying examples; all difficulties disappear, as if by magic, the moment we can free our minds of local time and the association of the *same hour* with the *same portion* of the day at *all places.* The great interest at present manifested in the attempts to reach the North Pole calls for some consideration of universal time in the extreme north. Commencing at the equator, it is easy to see that the day and night ring, Fig. 46, would represent the days and nights of 12 hours at all seasons. As we go north, however, this ring represents the *average* day and night. When we reach the Polar Circle, still going north, the *daily* rising and setting of the sun grad-

ually ceases till we reach the great one-year day at the Pole, consisting of six months darkness and six months light. Let us now assume that an astronomical observatory is established here and the great equatorial placed precisely on the pole. At this point, *local time, day and night,* and *the date line,* almost cease to have a meaning. For this very reason universal time would be the only practical method; therefore, it *more* than stands the test of being carried to the extreme. Universal time would regulate working and sleeping here the same as at all other places. Strictly local time in this observatory would be an absurdity, because in walking around the telescope (pole) you would be in all instants of the 24 hours within five seconds! At the pole the day would commence at the same instant as at some assumed place, and the day and night ring would represent working and sleeping as at that place. Suppose this observatory to be in telegraphic communication with New York, then it would be best for the attendants to set their day and night to New York, so as to correspond with its business hours. Many curious supposi-

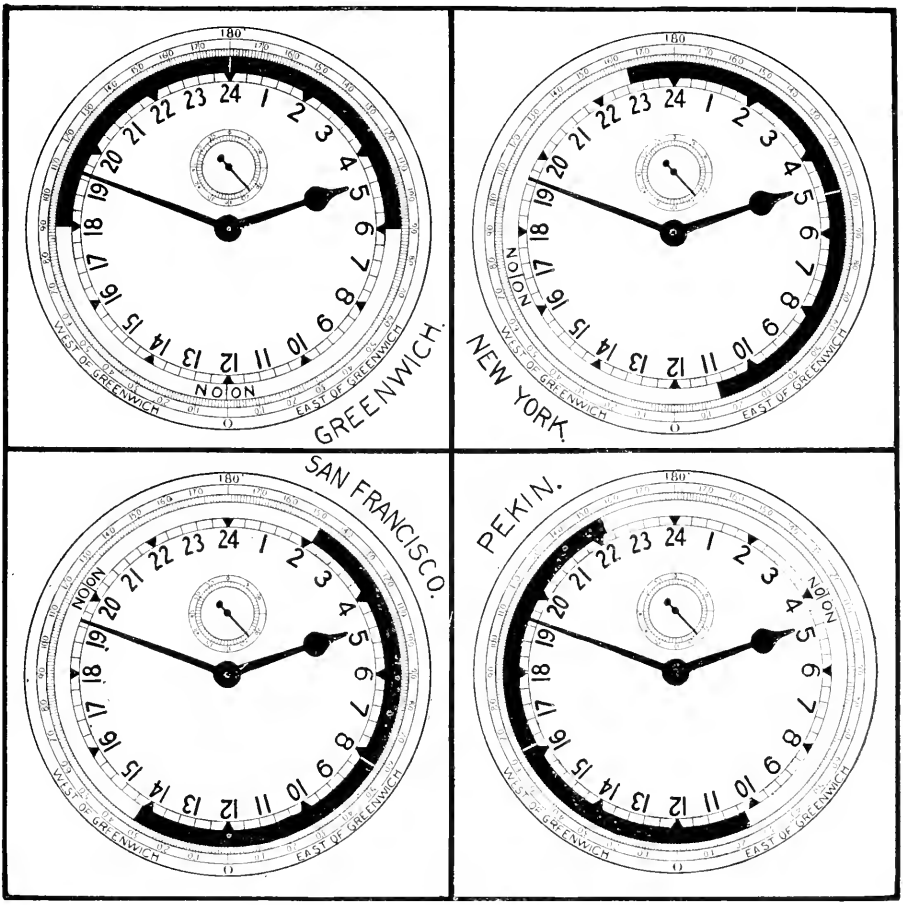


Fig. 46—Universal Time Dial Set for Four Places

'tions might be made about this polar observatory with its "great night" and equally "great day." It is evident that to keep count of itself it would be compelled to note *dates* and 24-hour *days* to keep in touch with us; so it would be forced to adopt the local day of some place like New York. This choice

would be free, because a polar observatory would stand on all the meridians of the earth at once.

We are now in a position to consider the next possible—and even probable—improvement in our clocks and watches. To minimize the next step it might be well to see what we can do now. Clocks are often regulated by electric impulses over wires. Electricians inform me that they can do this by wireless; but that owing to the rapid attenuation of the impulses it cannot be done commercially, over great distances. In the history of invention the first step was *to do something* and then find a way of doing it cheaply enough for general use. So far as I know, the watch in the wearer's pocket has not yet been regulated by wireless; but I am willing to risk the statement that the editor of Popular Mechanics can name more than one electrician who can do this. A watch to take these impulses might be larger than our present watches, but it would not stay larger and would ultimately become much smaller. You know what has happened since the days of the big "onions" described in the third chapter, Fig. 34; so get your electric watch and make it smaller at your leisure. We have made many things commercially practicable, which looked more revolutionary than this. Now throw out the mainspring, wheels, pinions, etc., of our watches and reduce the machinery part to little more than dial and hands and do the driving by wireless, say, once every minute. I feel certain that I am restraining the scientific imagination in saying that the man lives among us who can do this. I repeat, that we now possess the elementary knowledge—which if collated and applied—would produce such a watch.

Now I have a big question to ask—the central note of interrogation in this little scientific conversation with you, —does the man live who can make the earth automatically record its rotation? Do not be alarmed, for I am prepared to make a guess as to this possibility. A *direct* mechanical record of the earth's rotation seems hopeless, but let us see what can be done. You are aware that some of the fixed stars have a distinct spectrum. It is not unreasonable to suppose that an instrument could be made to record the passage of such a star over the meridian. Ah, but you say, there is no mechanical force in this. Do not hurry, for we have long been acquainted with the fact that things which, apparently, have no force can be made to liberate something which manifests mechanical force. We could now start or stop the greatest steam engine by a gleam of sunlight, and some day we might be able to do as much by the lately discovered pressure of light. That is, we can now liberate the greatest forces by the most infinitesimal, by steps; the little force liberating one greater than itself, and that one another still greater. A good example is the stopping of an electric train, from a distance, by wireless. The standard clock in Philadelphia, previously referred to, is a delicate instrument and its most delicate part, having the least force, moves a little valve every minute, and by several steps liberates the air pressure, 200 feet higher in the tower, to move the four sets of great hands. I am not traveling beyond the record when I say that the invisible actinic rays could be used to liberate a great force; therefore what is there unreasonable in the supposition that the displacement of the sodium line in the spectrum of a star might be made to record the earth's rotation? So I say to the electrician—the optician—the photographer—the chemist and the mechanic,—get together and produce this watch. Permit me, with conventional and intentional modesty, to name the new timepiece *Chroncosmic*. For pocket use, it would be *Cosmic watch*. In the first chapter I allowed to the year 2,000 for the production of this watch, but it is likely we will not need to wait so long.

Having stated my proposal for universal time as fully as space will permit and given my guess as to the coming cosmic watch, let us in this closing paragraph indulge in a little mental exercise. Suppose we copy the old time

ecturer on astronomy and "allow our ninds to penetrate into space." Blessed be his memory, he was a doer of good. How impressive as he repeatedly dropped his wooden pointer, and lo! It always moved straight to the floor; thus triumphantly vindicating universal gravitation!!!

We can think of a time system which would discard months, weeks and days. What is the meaning of the financial almanac in which the days are numbered from 1 to 365 or 366? Simply a step in the right direction, *away from the months and weeks*, so that the distance between any two dates may be seen at a glance. We would really be better without months and weeks. Now let us consider the year of the seasons as a unit—long since proposed by the astronomers—and divide it into 3,000 chrons. Clocks regulated by star transits, as at present, would divide this decimally, the fourth place being near enough to make the new pendulums of convenient length. This would throw out months, weeks and days, local time and the date line. Each of these chrons would represent the same time in the year, permanently. For example, 464.6731 would mark to a *dixmilliemechron* (a little more than one second) he point reached in the year; while the date does not, as I have shown in the irst chapter. But you still object that his is a great number of figures to use n fixing a point in the year. Let us see what it takes to fix a point in the year now, *August 24th, 11-16-32 P. M., New York standard time.* A pretty long story, but it does not fix the point of he year even then; for it would require the assistance of an astronomer o fix such a point in *any given* year, ay 1909. But 464.6731 would be ternally right in *absolute time* of the easons, and has only one meaning, vith no qualifications for any year vhatever. I believe the astronomers hould use a method something like his. Ah, but there is a difficulty in pplying this to the affairs of daily life hich looks insurmountable. This is aused by the fact that the *day* and *year* re incommeasurable. One of them cannot be exactly expressed in terms of the other. They are like the diagonal and side of a square. The day is now the unit and therefore the year has an interminable fraction; conversely, if we make the year the unit, then the day becomes an endless fraction. This brings us face to face with the local day which we ignored in our scientific year unit. We *must* regulate our labors, in this world, to day and night and, with the year unit, the chrons would bear no fixed relation to day and night, even for two days in succession. So the year unit and absolute time must be left to the astronomers; but the *day unit* and the uniform world day of *universal time* as explained in connection with Fig. 46 I offer as a practical system.

I am satisfied that all attempts to measure the year and the day by the same *time yard stick* must fail and keep us in our present confusion. Therefore separate them once for all time. Brought down to its lowest terms my final proposal is:—

1st. An equinoctial year unit for the astronomers, divided somewhat as suggested, but no attempt to make the divisions even approximate to days and hours. This would fix all astronomical events, absolutely. A variation in the length of the year would not disturb this system, since the year *itself* would be the unit. In translating this astronomical, or year unit time, into clock time, no difficulties would be added, as compared with our present translation of sidereal time into clock time. Deal with the *year unit* and *day unit* separately and convert them mutually when necessary.

2nd. A universal mean time day of 24 hours, as now kept at Greenwich, all human business being regulated by this time. Dates and the date line as well as leap years all being retained as at present.

3rd. Weight and spring clocks and watches to be superseded by the cosmic clocks and watches regulated by wireless impulses from central time stations, all impulses giving the same invariable time for all places.

4th. Automatic recording of the earth's rotations to determine this time.

To avoid any possibility of misunderstanding, I would advise never counting a unit till it is completed. We do this correctly with our hours, as we understand 24 o'clock to be the same as 0 o'clock. But we do not carry this out logically, for we say 24.30. How can this be so, since there is nothing more than 24 o'clock? It ought to be simply 30 minutes, or 0 hour 30 minutes. How can there be any *hour* when a new day is only 30 minutes old? This brings up the acrimonious controversy, of some years ago, as to whether there was any "year one." One side insisted that till one year was completed there could only be months and days. The other side argued that the "year one" commenced at 0 and that the month and date showed how much of it had passed. Test yourself,—is this the year 1909, of which only 8 months have passed; or is it 1909 and 8 months more? Regarding the centuries there appears to be no difference of opinion that 1900 is completed, and that we are in the 20th century. But can you tell whether we are 8 years and 8 months into the 20th century or 9 years and 8 months? It ought to be, logically 1909 years *complete* and 8 months of the next year, which we must not count till it is completed. Take a carpenter's rule, we say 1/4 in.—1/2 in.—3/4 in., but do not count an inch till we complete it. When the ancients are quoted,—"about the middle of the third hour" there is no mistake, because that means 2½ hours since sunrise. If we said the 1909th year that would be definite too, and mean some distance into that year. Popular language states that Greenwich is on the "first meridian"; strictly, it is on the zero meridian, or 0°. These matters are largely academic and I do not look on them as serious subjects of discussion; but they are good thought producers. Bidding you good-bye, for the present, it might be permissible to state that this conversational article on Time was intended to be readable and somewhat instructive; but especially to indicate the infinity of the subject, that thought and investigation might be encouraged.